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GENERAL ELECTRIC Review

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March, 1948

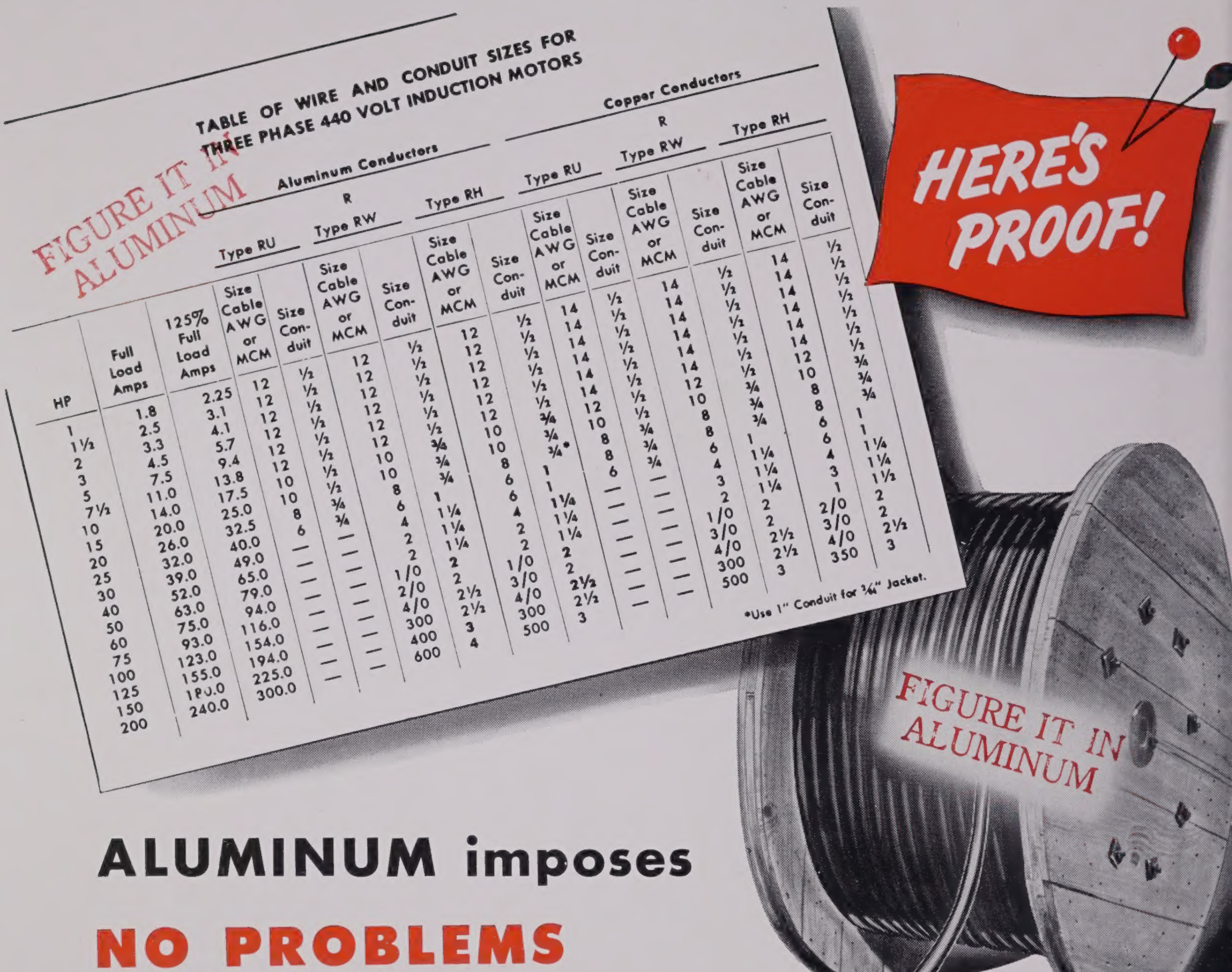

TABLE OF WIRE AND CONDUIT SIZES FOR THREE PHASE 440 VOLT INDUCTION MOTORS

			Aluminum Conductors						Copper Conductors					
			Type RU		R Type RW		Type RH		Type RU		R Type RW		Type RH	
HP	Full Load Amps	125% Full Load Amps	Size Cable AWG or MCM	Size Conduit	Size Cable AWG or MCM	Size Conduit	Size Cable AWG or MCM	Size Conduit	Size Cable AWG or MCM	Size Conduit	Size Cable AWG or MCM	Size Conduit	Size Cable AWG or MCM	Size Conduit
1	1.8	2.25	12	½	12	½	12	½	14	½	14	½	14	½
1½	2.5	3.1	12	½	12	½	12	½	14	½	14	½	14	½
2	3.3	4.1	12	½	12	½	12	½	14	½	14	½	14	½
3	4.5	5.7	12	½	12	½	12	½	14	½	14	½	14	½
5	7.5	9.4	12	½	12	½	12	½	14	½	14	½	14	½
7½	11.0	13.8	12	½	12	½	12	½	14	½	14	½	14	½
10	14.0	17.5	10	½	10	¾	10	¾	12	½	12	½	12	½
15	20.0	25.0	10	½	10	¾	10	¾	10	½	10	¾	10	¾
20	26.0	32.5	8	¾	8	¾	8	¾*	8	¾	8	¾	8	¾
25	32.0	40.0	6	¾	6	1	6	1	8	¾	8	¾	8	¾
30	39.0	49.0	—	—	4	1¼	6	1	6	¾*	6	1	6	1
40	52.0	65.0	—	—	2	1¼	4	1¼	—	—	4	1¼	6	1
50	63.0	79.0	—	—	2	1¼	2	1¼	—	—	3	1¼	4	1¼
60	75.0	94.0	—	—	1/0	2	2	1¼	—	—	2	1¼	3	1¼
75	93.0	116.0	—	—	2/0	2	1/0	2	—	—	1/0	2	1	1½
100	123.0	154.0	—	—	4/0	2½	3/0	2	—	—	3/0	2	2/0	2
125	155.0	194.0	—	—	300	2½	4/0	2½	—	—	4/0	2½	3/0	2
150	180.0	225.0	—	—	400	3	300	2½	—	—	300	2½	4/0	2½
200	240.0	300.0	—	—	600	4	500	3	—	—	500	3	350	3

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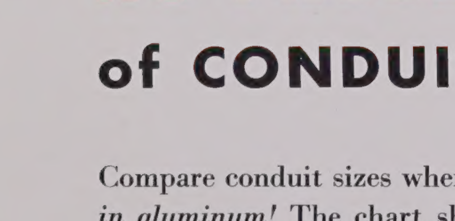
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GENERAL ELECTRIC Review

MARCH, 1948
Vol. 51, No. 3

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THE COVER

Another application of electronic heating in industry—this one in the manufacture of motorcycles. In the background of the photograph is the electronic heater which, with its simple controls and ready production of localized heat, enables the operator to carry on rapidly and conveniently his operations of brazing and heat-treating with assurance of producing quality work. See "Electronic Heating," page 48.

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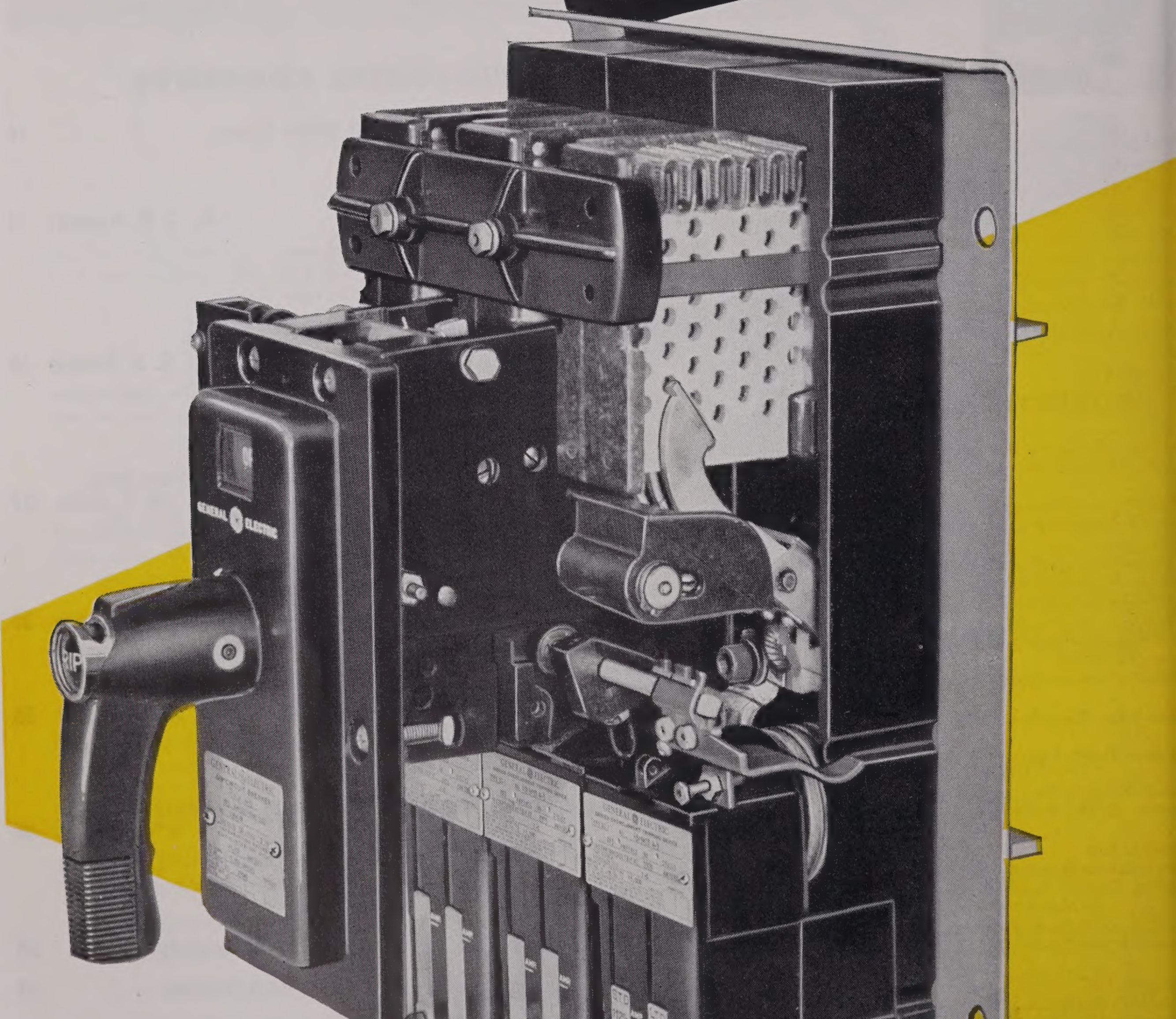

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COSMIC RAYS . . . . Part I

Elementary particles and radiations of atomic and nuclear physics, a familiarity with which is a necessary prelude to a better understanding of cosmic rays

By Dr. C. W. HEWLETT
Consulting Physicist, West Lynn and River Works Laboratories
General Electric Company

C. W. Hewlett

JUST before the turn of the present century, there were made in physics a number of startling discoveries which were destined to have a profound influence on the whole field of science, on the field of industry, and even on philosophy.

These were the discoveries of x-rays, of the electron, and of the phenomena of radioactivity. It had been known for a long time that, when exposed to the atmosphere, even the most carefully insulated conductors would lose—at a measurable rate—any electric charge supplied to them. The new discoveries suggested that the mechanism of the loss-of-charge phenomenon was an electrical conductivity conferred upon the atmosphere by the presence of charged atomic fragments called ions. At that time, the assumption seemed obvious that these charged ions were produced by the radiations from radioactive substances known to be present in the atmosphere and in the superficial layers of the earth. Great curiosity was therefore aroused as to the generality of the distribution of radium and other radioactive substances.

It was also realized that the new ideas concerning the ionization in the atmosphere should have important bearings on meteorological phenomena, and that investigations of atmospheric electricity should lead to a new and better understanding of complex weather phenomena. The old question of the age of the earth was reopened, since the newly discovered source of terrestrial heat arising from the disintegration of radioactive substances should extend the time interval during which the earth had cooled by an amount that could be estimated only by means of a general survey of the distribution of radioactive substances over the surface and below the surface of the earth. Assuming that the presence of ions in the atmosphere was due to the radiations from widely distributed radioactive substances, it was apparent that one very convenient way to study this distribution was to investigate the ionic density in the atmosphere in as many places, and under as widely varying conditions, as possible.

In 1908, when I began my graduate study, I was associated with a young man, by the name of W. W. Strong, who had just received his PhD for a research on the measurement of ionization in closed vessels. He had devised an ingenious electrometer of small electrostatic capacity, quantitatively calibrated it, and had enclosed it in a metal can. The reading of the electrometer could be observed through a small glass window in the can; and, from the changes of these readings with time, the number of ion pairs created per second in the can could be calculated.

With that equipment, Strong had studied the rate of ion production in the laboratory, in cellars and in mines, on hill tops and over Baltimore Bay, in day time and at night, in winter and in summer, and in many other situations. His mind was concerned with the distribution of radioactive substances, and he interpreted his results in the light of ionization produced in his closed vessel by alpha-, beta-, and gamma-rays from exceedingly sparsely distributed uranium, radium, and other radioactive substances in the soil, rocks, water, and atmosphere in the neighborhood.

Following my graduate student days, I spent a year and a half during 1912 and 1914 on the nonmagnetic survey yacht *Carnegie*, belonging to the Carnegie Institution of Washington. During passages in the Pacific and Atlantic Oceans, I made studies of the various aspects of atmospheric electricity, and among these studies were daily measurements of the electrical conductivity of the air and a direct measurement of the amount of charged radioactive ions in the atmosphere.

In making those measurements, the ions were collected on a negatively charged copper wire suspended in the air above the ship's deck. The wire was maintained at 2500 volts negative for about one hour, then it was quickly coiled up and inserted in an ionization chamber containing a charged electrode connected to an electrometer of small capacity. The wire so treated always exhibited considerable radioactivity. By measuring the rate at which this activity decayed, conclusions were drawn as to the identity of the collected radioactive substance, and from the initial intensity of the ionization the quantity of the collected radioactive substance was inferred. Just as Strong had done, I interpreted my measurements in terms of the known radioactive substances which I considered to be present in small quantities in the sea water and brought in by the wind from more or less distant land masses.

Later, however, while I was studying these decay curves I was struck by the frequent appearance of

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This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 11 to 16.—Ed.

bursts of ionization in the ionization chamber. These bursts were evidenced by sudden drops of potential of the electrometer. I called the attention of my chief to this phenomenon and wanted to mention it in the publication we were preparing. He insisted that the bursts could be explained as random variations of reasonable probability, and the final result was that the material was published without reference to them. There is no doubt now that these bursts of ionization were manifestations of a now well-known aspect of cosmic-ray phenomena.

In 1911, Hess, a German physicist, published an account of studies made of ionization in closed vessels while in balloon flights. He found that the ionization increased rapidly with altitude, and on the basis of this fact he proposed that a large part of this ionization was due to a penetrating radiation coming from above, probably from interstellar space. This conclusion has since been confirmed, and also that only a small part of the ionization which had previously been observed was due to radioactive substances.

The radioactive substances collected on charged wires exposed in the atmosphere are radioactive isotopes resulting from nuclear disintegrations caused by cosmic rays. At first, the penetrating power of this extra-terrestrial radiation was deemed to be at least ten times as great as any other ray previously known. Kolhorster and Hess concluded that cosmic rays would pass through six and one half times as much atmosphere as would the gamma-rays from ThC, the hardest known gamma-rays. We now know that their penetrating power is even greater than was then supposed, and that a measurable number of these rays can pass through as much as 75 ft of lead.

Fundamental Processes and Reactions

Before giving detailed consideration to the properties and nature of cosmic rays, a review will be made of

Chart I

ELEMENTARY PARTICLES AND RADIATIONS OF ATOMIC AND NUCLEAR PHYSICS AND THEIR MOST IMPORTANT PROPERTIES

Name	Charge: in units of 10^{-10} electrostatic units* (E.S.V.)	Mass: in units of 10^{-28} gram	Symbol	Diagrammatic Representation†	Associated Ray	Effect of Electric or Magnetic Fields on Ray	Where Found	Comments
Negatron, or negative electron	−4.80	9.1	$\bar{e}$	⊖	β-ray, or Cathode ray	Deflection (Right to left)	Nuclear planets	These are closely related, and one of each kind can be produced simultaneously when a gamma-ray disappears
Positron, or positive electron	+4.80	9.1	$\overset{+}{e}$	⦶	β-ray	Deflection (Left to right)	In between atoms as a result of nuclear transformations, also in pair production	
Proton, or hydrogen nucleus	+4.80	16,610	p, H^1	⊕	Proton ray	Deflection	The positively charged constituent of all atomic nuclei	
Neutron	0	16,630	n	○	Fast or slow neutron	None	An electrically neutral constituent of all atomic nuclei. (They exist free due to atomic disintegration)	
Deuteron, or heavy hydrogen nucleus	+4.80	33,200	d, H^2	○⊕	Deuteron ray	Deflection	The nuclei of heavy hydrogen or deuterium. (Ionized deuterium atoms are deuterons)	
α-particle, or helium nucleus	+9.60	65,970	α, He^4	○⊕ ⊕○	α-ray	Deflection	The nuclei of helium atoms. (Doubly ionized helium atoms are α-particles)	
Meson	+4.80	≈ 1,700	$\overset{+}{\mu}$	⊜	Meson	Deflection	Cosmic rays	These are closely related, differing only in charge
	−4.80	≈ 1,700	$\overset{-}{\mu}$	⦷	Meson	Deflection	Cosmic rays	
	0	≈ 1,700	μ	○	Meson	None	Cosmic rays	
Neutrino	0	? very small	M		Neutrino	None		
Photon Light Quantum	0	$h\nu/c^2$	$h\nu$	—∿—	Light ray	None	In all visible light phenomena.	These are closely related, all being electromagnetic disturbances
X-ray	0	$h\nu/c^2$	$h\nu$	—∿—	X-ray	None	From x-ray and cathode-ray tubes.	
Gamma-ray	0	$h\nu/c^2$	$h\nu$	—∿—	Gamma-ray	None	From x-ray tubes and radioactive substances.	

* One electrostatic unit of charge is that charge which when placed at a distance of one centimeter from an equal and like charge will be repelled by the latter charge with the force of one dyne.

† As used in the illustrations of this article. There are no universally accepted diagrammatic representations.

what is known about the fundamental particles and entities, the behavior of which will be invoked to explain those phenomena.

Chart I shows the principal known facts about these particles. With each of these types of particles there is associated a so-called "ray," which is simply a fast-moving particle. A beta-ray, for example, is a fast-moving negatron or positron. A proton ray or a deuteron ray is a proton or deuteron of high velocity. An alpha-ray is a high-velocity helium nucleus, and so on. X-rays and gamma-rays are electromagnetic radiation and are called photons. Generally speaking, x-rays have energies from a few to several hundred thousand electron volts, and gamma-rays have energies from several hundred thousand to millions and billions of electron volts.

Electrons

Beta-rays, either positive or negative, are deflected in electric and magnetic fields, but the deflections are in opposite directions for the two different signs of charge. This action is illustrated in the upper-left section of **Fig. 1**, where the magnetic field is assumed to be perpendicular to the plane of the page.

Beta-rays in passing near atoms sometimes detach one or more of the extra-nuclear electrons in the act called ionization. This is illustrated in the upper-right section of **Fig. 1**. The recapture of electrons by ionized atoms gives rise to optical and x-ray emission phenomena. The outer electrons of an atom, by interaction with those of another atom, are responsible for chemical phenomena; and, in metals and semiconductors, they are responsible for electrical conduction and various thermo, photo, and other electrical effects. The ionization of a gas by the action of beta-rays results in electrical conduction of the gas.

Very-high-energy beta-rays, besides producing ionization that fritters away their energy a few volts at each ionization act, can lose all their energy in a single encounter with an atom. This loss can occur when a high-energy beta-ray passes quite close to an atom nucleus. In this act, the high-speed electron is brought practically to rest, and its kinetic energy is converted into a high-energy gamma-ray, or photon, which travels on in the direction of the original beta-ray. This is illustrated in the lower-left section of **Fig. 1**. It will be seen later that this kind of event takes place in cosmic-ray phenomena. Beta-rays are not known to produce nuclear disintegrations.

Positive electrons are quite different from negative electrons aside from the fact that they have opposite charges. Positive electrons have a very short life. Whenever a positive electron approaches sufficiently near to a negative electron, the two vanish, and two photons are created. If the electrons have low speeds, the two photons of equal energy travel away in opposite directions. The rest energy of each electron is M_oC^2, and so each of the two photons emitted when the two electrons vanished have energy $h\nu \approx 500{,}000$ electron volts. This act is illustrated in the lower-right section of **Fig. 1**.

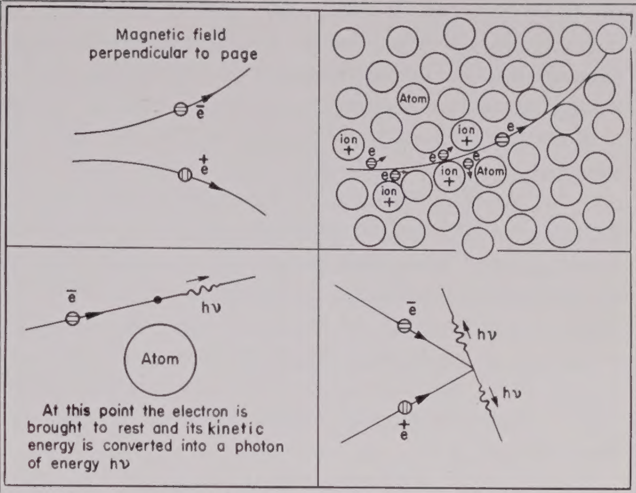
Magnetic field perpendicular to page
$\bar{e}$
$\overset{+}{e}$
Atom
ion
$\bar{e}$
hν
Atom
At this point the electron is brought to rest and its kinetic energy is converted into a photon of energy hν
$\bar{e}$
hν
hν
$\overset{+}{e}$

Fig. 1. Action of electrons under different conditions

The upper-left section shows diagrammatically the bending of positive and negative electron paths (β rays) by a magnetic field perpendicular to the velocities of the moving electrons.

The upper-right section represents the passage of a negative electron (negative β ray) through an assemblage of atoms or molecules. The moving electron in passing near or through atoms splits off electrons from the atoms, leaving positively charged atomic "ions" and free electrons.

The lower-left section shows a very energetic β-ray passing near an atom and suffering the loss of nearly all its energy of motion by electromagnetic interaction with the atom. The lost energy is converted into electromagnetic radiation and proceeds on its way as a photon of energy $h\nu$.

The lower-right section shows the annihilation of a slow-moving pair of positive and negative electrons with the simultaneous appearance of two photons of electromagnetic radiation, each of energy $h\nu$. The combined momentum of the two photons will be the sum of the momenta of the two electrons.

The positive electron was predicted theoretically from wave mechanical studies before it was discovered experimentally. By his wave mechanical theory of the electron, Dirac predicted electrons with negative as well as positive rest energy. He postulated that ordinarily all negative-energy states are filled so that these electrons are unobservable. According to this theory, a one-million-volt photon should be able to expend its energy in lifting an electron from its negative-energy state of $-500{,}000$ electron volts to a state of positive energy of $+500{,}000$ electron volts where it becomes observable as a negative electron at rest. The hole left in the negative-energy states appears as a positive electron. This view provides for the conservation of electric charge in the transformations considered.

Protons

Proton rays are also deflected in electric and magnetic fields, but, owing to their greater momentum, those of even moderate energy are deflected much less than are beta-rays. For the very high energies, however, on account of the rapid increase of mass with speed, beta-rays become more like proton rays as far as deflectability is concerned. Proton rays produce far greater ionization density than do beta-rays, partly because, for the same energy, the former move slower than the latter and hence spend a longer time in the vicinity of a given atom, thus having greater opportunity to exert a disrupting effect. The other reason why proton rays cause more ionization than do beta-rays is that, because of their greater momentum, they are deflected less from their paths in approaching atoms and consequently make closer approaches. On account of their greater momentum, proton rays are able occasionally to enter atomic nuclei, and when doing so they are likely to cause nuclear transformations resulting in the formation of other chemical elements or isotopes.

Near the ends of their ranges, where they have lost a large part of their velocity owing to acts of ionization, protons remain so long in the neighborhood of the atoms near which they pass that they lose energy at a much greater rate than before. That is, near the end of its range, a proton ray ionizes much more effectively than in earlier parts of its range, and the density of ionization it produces is much greater at the end of its range. These characteristics have an important bearing on the interpretation of certain features of cosmic-ray phenomena.

Recent work, both theoretical (wave mechanics) and experimental, indicates that very-high-energy proton rays upon striking atoms may themselves split up, giving rise to a number of plus and minus mesons, each moving with the same velocity as the parent proton. This would suggest that the proton may be composed of an odd number of mesons, the number of positive mesons being one more that the number of negative mesons. This process will later be given consideration in its bearing on cosmic-ray phenomena.

Deuteron Rays and Alpha-rays

These rays produce the same kinds of effects as do proton rays. The magnetic and electric deflections are less, but the density of ionization is greater than for proton rays for the same reason that the same is true for proton rays compared to beta-rays. The nuclear disintegration effects are also much greater for deuteron rays and alpha-rays than for proton rays, deuteron rays being particularly effective in this respect.

Neutrons

Neutrons have no electric charge, and for that reason they do not react readily with atoms unless they actually strike or enter atomic nuclei. If a neutron ray strikes a hydrogen atom head on, the neutron comes nearly to rest, and the hydrogen nucleus (the proton) takes up the energy of motion and proceeds on in the direction in which the neutron was going, and with nearly the same velocity that the neutron had. In fact, this was the way in which neutrons were discovered. When neutrons and hydrogen atoms come close together, there is also the possibility that the proton and the neutron will remain together, forming the nucleus of the heavy hydrogen atom, or the deuteron. This is a fairly frequent occurrence when neutrons enter hydrogenous substances. With some other light elements—such as carbon, for example—fast neutrons can be slowed down by successive collisions with the atoms, and this may be the only change. The heavier the atom the less the energy lost by the neutron at each elastic collision and, consequently, the greater the number of collisions required before the neutron is reduced in velocity to the average value corresponding to the prevailing temperature.

The most spectacular effects produced by neutrons are those of transmutation which they may produce when they enter the nuclei of atoms. The neutrons find it particularly easy to enter nuclei since, being without charge, they do not have to overcome electric fields in the nuclei. Upon entering, they upset the nuclear equilibrium and usually cause the nucleus to eject various nuclear particles, giving rise to different elements and isotopes which are frequently radioactive. The capture of neutrons by U^{238} starts a nuclear reaction which results in the formation of Pu^{239}, and the capture of neutrons by U^{235} and Pu^{239} results in the fission of these nuclei. However, these phenomena are outside the scope of this article.

Mesons

One of the most generally accepted views at the present time is that all atomic nuclei are built up of protons and neutrons. **Fig. 2** is a schematic representation of an atom of the element lithium. The actual atom is three-dimensional of course. The illustration shows a nucleus composed of three protons and four neutrons. The question naturally arises as to the nature of the force field that governs the way in which these particles are arranged in the nucleus. At certain distances the force between the particles must be attractive, otherwise the particles would not associate; at very much smaller distances the force must be repulsive, otherwise the particles would approach one another indefinitely closely.

It is reasonable to suppose that ordinary coulomb force (e_1e_2/r^2), electromagnetic force ($H\ e\ v$), and gravitational force (m_1m_2/r^2) are present. Besides these there is probably present another type of force known as "exchange force." The latter force contribution may be likened to the similar force that holds two hydrogen atoms together to form a hydrogen molecule. The existence of this force is demonstrated by a wave mechanical treatment of the hypothetical process in which two hydrogen atoms, when not too far apart, exchange their orbital electrons in much the same manner that two boys, each possessing a ball, might throw the balls back and forth to one another.

The quantitative treatment of the problem, taking into consideration the coulomb, electromagnetic, gravitational, and exchange forces, indicates that at relatively great distances the two atoms attract one another and that, as the separation decreases, the attractive force diminishes until finally, at a certain distance of separation, the force becomes zero. For a still shorter distance, the force becomes a repulsion. Where the force becomes zero, the distance between the two atoms is that which should exist in the hydrogen molecule. In fact, the quantitative prediction of the theory gives with great accuracy the normal interatomic distance in the hydrogen molecule, and also the heat of dissociation of the hydrogen molecule.

In 1935, a Japanese physicist, H. Yukawa, proposed a somewhat similar theory to account for the nuclear forces that hold together the nuclear components. He proposed that a proton can emit a positively charged particle, thereby becoming a neutron; while a neutron can emit a negatively charged particle, thereby becoming a proton. Therefore, when two protons approach each other they may exchange these emitted particles in the same manner as when two hydrogen atoms approach each other they exchange orbital electrons. This would give rise to an exchange force which, when combined with the coulomb, electromagnetic, and gravitational fields present in the nucleus, would produce a total field of the same nature as that described for the hydrogen molecule. The same kind of argument holds for the interaction between two neutrons.

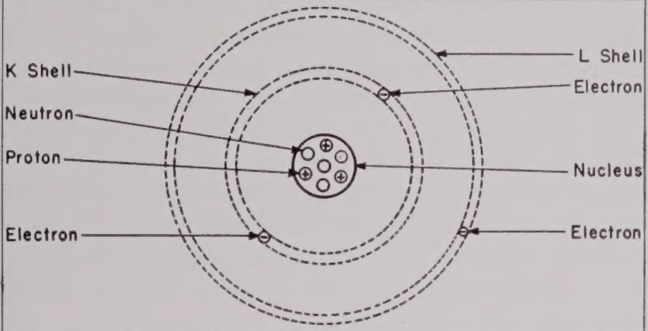

Fig. 2. Features of atomic structure as exemplified by that of lithium

The group of particles in the small central circle is known as the "nucleus" of the atom, and the total number of those particles determines the mass of that atom. In the nucleus of this atom of lithium are three protons and four neutrons. At distances of many nuclear diameters, and in so-called "shells," are electrons, the total number of which is equal to the number of protons in the nucleus. The number and arrangement of these extranuclear electrons determine the chemical properties of the element; consequently the number of protons in the nucleus of an atom is unique for each element.

For the great majority of elements, the number of neutrons present in the nucleus is not limited to a single number. That is, while all atoms of a given element have the same number of protons, and hence the same chemical properties, some of those atoms may have different numbers of neutrons and hence different masses. The atoms that are thus unlike may be regarded as different members of a given element family, and they are called "isotopes" of the given element.

An atom or molecule which has temporarily lost or gained one or more electrons in its extra-nuclear group is called a positive or negative "ion" respectively. Free electrons are also sometimes referred to as negative ions.

In the case of the interaction between a proton and a neutron—upon interchange of their emitted charged particles—each becomes alternately a proton and a neutron in rapid succession. This also gives rise to the same type of force field. To provide an exchange force field of the order of magnitude that will account for the binding energy in systems of the size estimated for atomic nuclei, it was found that the mass of one of these charged particles emitted by a proton or neutron should be about 180 times that of the mass of an electron.

To account for beta-ray decay in certain nuclear transformations (transmutations in which the emission of beta-rays is the only observable radioactive phenomena), Yukawa made the further hypothesis that, during the interval while one of these emitted charged particles is free from its proton or neutron, it is unstable and may disintegrate into an electron and a neutrino, all of its energy being divided between these two. This energy includes its rest-mass energy, equivalent to about 90 million electron volts, so that the total energy available for distribution when the particle decays is of the order of 100 million electron volts.

The foregoing hypothesis and the quantitative deductions drawn from it were made before the discovery of the meson as a constituent of cosmic rays; and the discovery of these particles in cloud-chamber observations was regarded as a brilliant confirmation of the Yukawa Theory. The meson hypothesis then serves the following threefold purpose: (1) of providing a mechanism for explaining the binding forces holding together the protons and neutrons in atomic nuclei; (2) of providing a mechanism for the beta-ray decay in certain nuclear disintegrations; and (3) of serving as one kind of penetrating radiation observed in cosmic-ray phenomena.

So far, mesons have been observed only in cosmic-ray processes, and here they are presumably produced by the disintegration of positively charged particles, such as protons. During their short life the mesons produce ordinary ionization, the density of which is intermediate between that produced by proton rays and beta-rays. The slower the mesons move, the shorter their average life. The average lifetime of these particles is supposed to be given by $t=t_o/\sqrt{1-(v/c)^2}$ where v is the velocity of the meson, c is the velocity of light, and t_o is the mean lifetime for a meson at rest.

Mesons observed at sea level have half-lives of 1 to 2 microseconds. The average life is estimated by comparing the absorption of mesons that have traveled a long distance through air with the absorption for mesons that have traveled the much shorter distance through the same mass of liquid water. If the lives of mesons were long compared with the time required to pass through the given air path, the absorption would be the same in the two cases. But it is found that when the mesons have to travel the greater distance, they are absorbed more; that is, the longer they spend in passing through a given amount of matter, the more of them that disappear. Moreover, cloud-chamber pictures have actually recorded the death of mesons. When a meson dies, a negatron or a positron ray and a neutrino are born. The reason it is necessary to introduce the unobserved neutrino is that the total amount of the energy corresponding to that of the meson is not found in the daughter beta-ray.

Neutrinos

The quantitative consideration of the beta-ray decay of certain isotopes presents difficulties of interpretation in view of the principles of the conservation of energy and of momentum. As an illustration, consider the case of the radioactive transmutation of the isotope P^{32} to the stable S^{32}. The mass difference between these two atoms is known to be equal to the mass of one electron plus the mass equivalent of 1.70 Mev (1.70 million electron volts), but cloud-chamber observations of the radioactive rays accompanying the transformation reveal only a beta-ray accompanying each transformation. Therefore, in the act of transformation of the atom P^{32} to S^{32} with the emission of a beta-ray, there is 1.70 Mev of energy to be divided between the products of the change, which will be at least the beta-ray and the daughter atom S^{32}.

The actual distribution of the energy will be determined by the law of conservation of momentum. Since the mass of S^{32} is so much greater than that of the emitted electron, the speed of the electron should be greatly in excess of that of the "recoil atom," and consequently nearly all the energy set free should be taken by the beta-ray. According to this premise, the decay of P^{32} will take place with the emission of beta-rays of one energy value; namely, 1.70 Mev. Actually, it is found that the beta-rays have a continuous distribution of energies up to a maximum value of about 1.69 Mev. This maximum value is that which would be expected for all the beta-rays. What becomes of the remainder of this disintegration energy for those beta-rays that are emitted with less than the maximum value of 1.70 Mev?

Fermi, following a suggestion by Pauli, proposed that in addition to the electron another particle, that he named the "neutrino," having properties like those of a very light neutron, is emitted along with the beta-ray and carries the energy balance. This particle should be difficult to detect, as it has no charge and very small mass. It is, however, capable of carrying off the required energy.

According to Fermi's Theory, the energy of 1.70 Mev should appear as kinetic energy of the recoil atom, the electron (or beta-ray), and the neutrino. Since the electron and the neutrino have but small mass compared to that of the recoil atom, they will absorb nearly all the energy. If the electron takes nearly all the energy and the neutrino only a small amount, then the measured beta-ray energy will be nearly 1.70 Mev. If, on the other hand, the neutrino takes nearly all the energy, the beta-ray will not be detectable. In these transformations, very-low-energy beta-rays are actually found. The probability of either of these extreme divisions is rather small. Much greater is the likelihood that there is, roughly, equality of energy distribution. In fact, the Fermi Theory predicts very accurately the energy distribution actually found among the emitted beta-rays.

This type of evidence gives rise to the hypothesis of the existence of the neutrino. As already mentioned, the particle has never been observed by effects produced after its birth, but the decay of mesons is also a process in which the emission of neutrinos serves as a way of satisfying the laws of energy and momentum conservation in that act.

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Photons

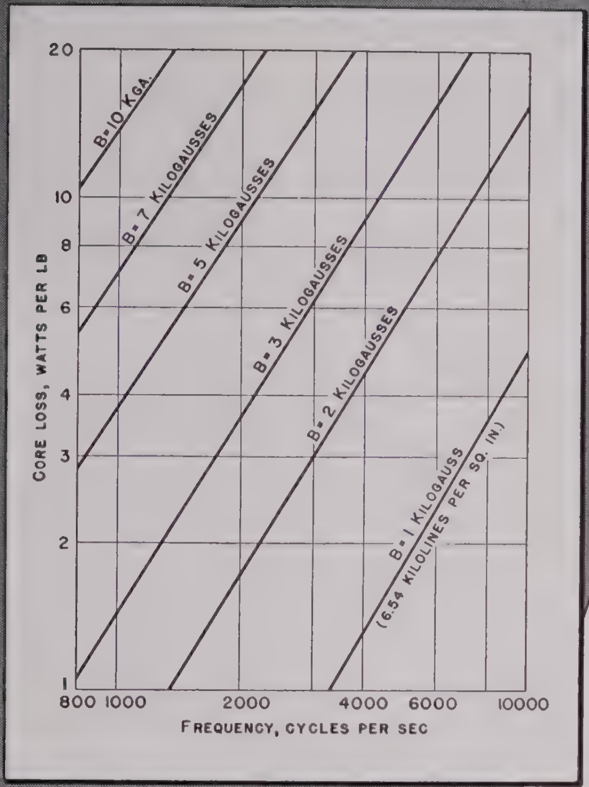
X-rays produce ionization chiefly by what is called the Compton Effect: An x-ray photon encounters a loosely bound electron and imparts some of its energy and momentum to it. The result is that the electron escapes from its atom with a certain speed, the atom recoils with a much lower speed, while the photon drops in energy from $h\nu_0$ to $h\nu$. The direction and velocity of motion of the ejected electron, those of the recoil atom, and the direction and frequency of the altered photon are such as to satisfy the energy and momentum conservation laws. Gamma-rays may produce ionization in the same manner, and in addition they may produce ionization in encounters with *tightly bound* electrons by giving up all their energy and ejecting the electron from the atom holding it. The latter type of ionization is referred to as photoelectric ionization. Gamma-rays may also produce nuclear disintegrations.

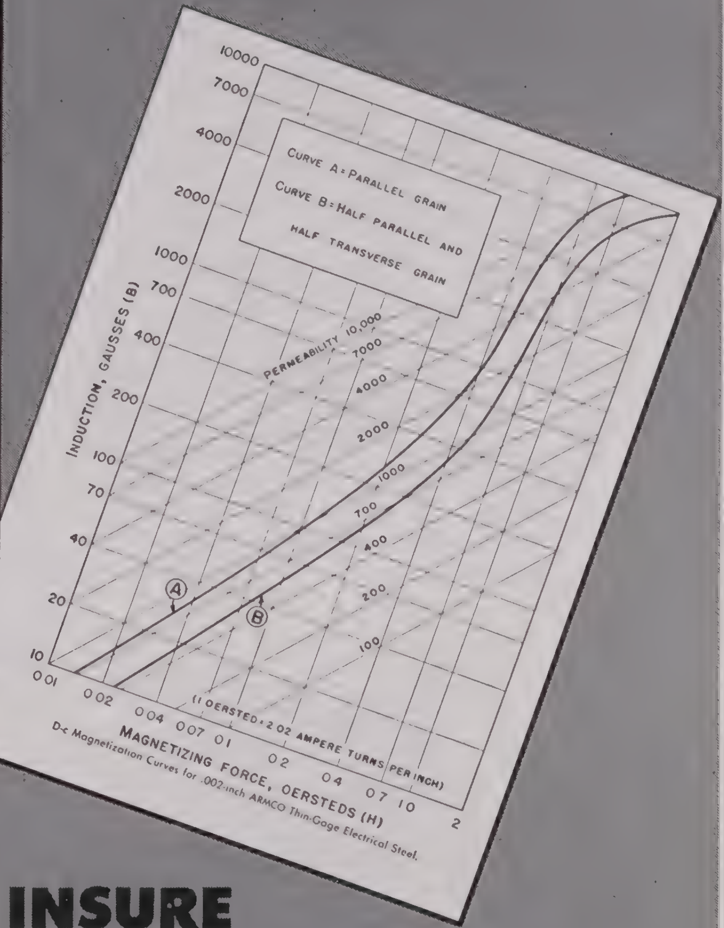
There is still a third type of ionization produced by high-energy photons, and this is the strangest of all: Frequently, a very-high-energy photon upon close encounter with an atom will be converted entirely into a negatron-positron pair which are ejected in the same general direction as the original photon giving rise to them. This pair creation and the related Dirac Theory have already been mentioned in the Electrons section of this article. About 1 Mev of the energy of the photon is required to provide the rest mass of the two particles, and the remainder of the photon energy appears as kinetic energy of the two particles. Conservation of charge is maintained since equal quantities of positive and negative electricity appear.

The foregoing process takes place for photons of billions of volts energy, so that the resulting negatron and positron rays are still of very high energy. As has already been stated, these very energetic beta-rays can, in passing atoms, emit high-energy photons, and these can in turn give rise to new negatron-positron pairs. This is a multiplicative process and can continue until the succeeding generations of beta-rays and photons have decreased in energy to the extent that the pair creation ceases. In between the transformations, all the rays will produce ionization.

It is thus apparent that a single very-high-energy gamma-ray or beta-ray can initiate a burst of ionizing particles which will produce a large amount of ionization in a relatively small space. It is to be noted here that this process is one of the mechanisms responsible for some of the cosmic-ray phenomena. The "burst" or "shower" of ionizing rays is called a "cascade."

(To be continued with a description of experimental methods of investigation, principal facts about cosmic rays, and attempts to explain observed data.)





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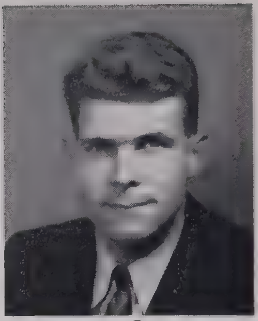
The performance of small motors for particular applications assured by instruments which reveal data not measurable by usual testing equipment

By E. G. DOWNIE
Works Laboratory, Fort Wayne Works
General Electric Company



E. G. Downie

MANY models of small control motors used during the war were required to meet performance specifications that could not be measured by the usual motor-testing equipment.

For example, certain d-c aircraft motors were equipped with magnetic brakes which stopped the shaft within a few revolutions, or even within a few degrees, after the motor or brake excitation was removed. One type of a-c series motor was required to stop in a certain number of revolutions (before starting up again in the opposite direction) when the armature connections were reversed with respect to the field.

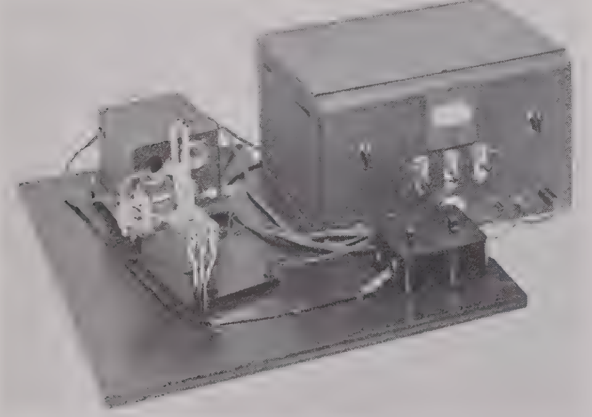


Fig. 1. Instrument for counting the number of shaft revolutions of a d-c motor shaft after motor and brake are de-energized. The motor is shown in place at the left

To make certain that the motors were meeting these specifications, special testing devices were designed and constructed for production use. These devices included three instruments which performed the required tests on three general types of motors.

For D-c Brake-equipped Motors

The first instrument is an electronic revolution counter, designed to count the number of revolutions (approximate range from two to twenty) made by a d-c motor shaft after the motor and brake are de-energized. The photocell system of rotation indication, with one or more small mirrors on the motor shaft reflecting light into a photocell, is used in this counter for picking up motor revolutions.

The electronic-counter circuit operates on the principle of discharging, by means of a thyratron tube, a fixed charge from a small capacitor into a large capacitor with each impulse received, and then reading the charge on the large capacitor with a vacuum-tube-voltmeter circuit as a measure of the number of impulses received.

An intermediate thyratron stage is required to make the final impulses independent of the intensity and duration of the light impulses; and a third thyratron, triggered by inductive kick from the motor, serves to energize the counting circuit at the instant of motor power cutoff. A more complete description of operation, with the circuit diagram, has been previously published.(1) **Fig. 1** shows this instrument with the motor being tested in place at the left.

While the electronic revolution counter served very well in production testing of the d-c brake-equipped motors, it could not be adapted to the reversing series a-c motor, mentioned previously, for several reasons. The voltage transient from switching an a-c motor is variable and hence cannot be used as a reliable means of triggering the counting circuit. The problem of stopping the count at the instant of reversal would considerably complicate the device.

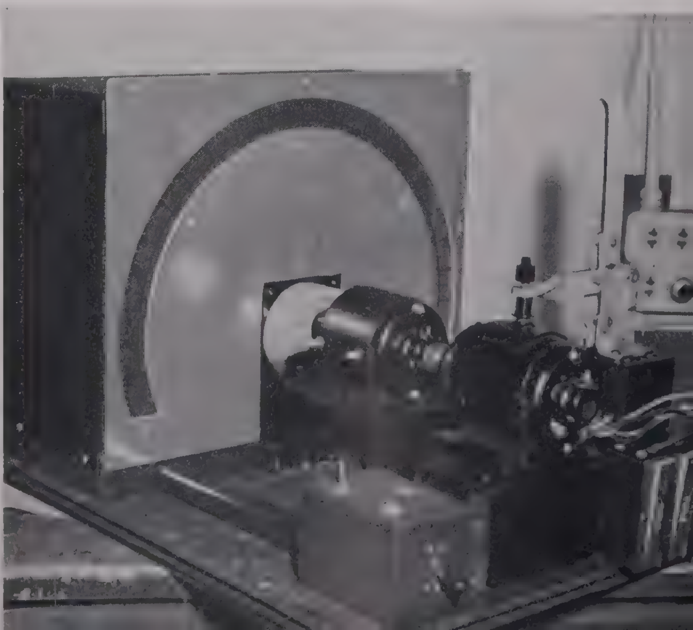


Fig. 2. A-c series motor test. Light seen on the scale is reflected from a mirror on the low-speed shaft of a 36:1 reduction gear box located back of the scale

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(1) "Electronic Counter and Tachometer," by E. G. Downie, GENERAL ELECTRIC REVIEW, Nov., 1944, p. 50.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 18 to 20.—ED.

For Reversing Series A-c Motors

A quite different, yet simple, instrument was built to count the number of revolutions made by the series a-c motor from the instant of armature-current reversal to motor standstill. A front view of the completed equipment, with motor in place, is shown in **Fig. 2**. The motor drives a 36:1 reduction gear box through a friction loading element consisting of a shaft with two commutators and adjustable-pressure brushes. The friction load is prescribed in test specifications.

The low-speed shaft of the gear box, extending into the main cabinet at the rear (**Fig. 3**) carries a 45-deg mirror that reflects light from an axial light to the transparent calibrated scale.

Operation is based on the ability of the eye to retain the image of the light beam at its point of reversal on the scale. The reversal of the motor is accomplished by reversing the armature connections with respect to the series field. The relay which reverses the motor to make a test is controlled by the thyratron and photocell shown at the top center in **Fig. 3**.

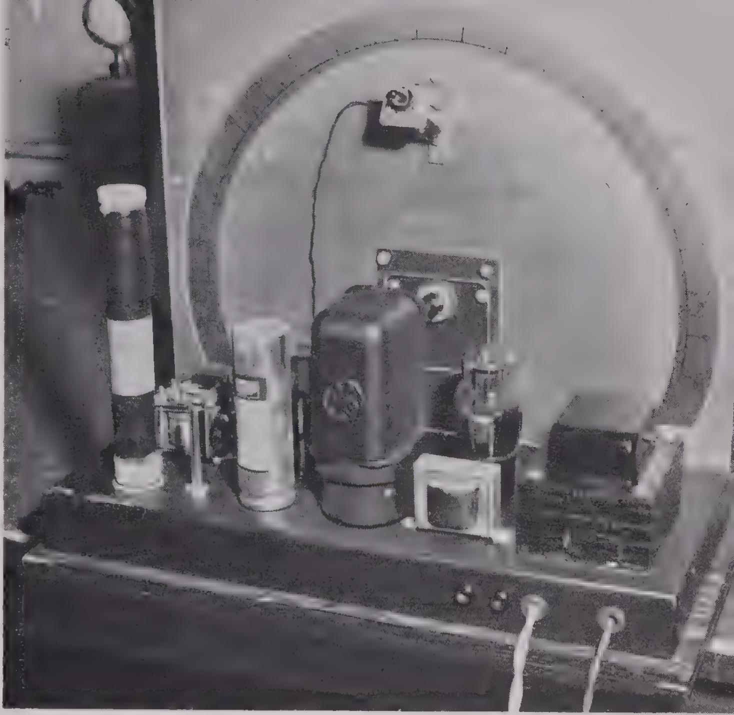
Fig. 3. Rear view of the test set-up shown in Fig. 2. Photocell and thyratron tube are located at the top-center region of the scale

The light falling on the scale also strikes the photocell as the light beam reaches the vertical position. The desired initial rotation of the motor is selected by an additional reversing switch, and a test reading is made by closing a push-button switch to energize the reversing circuit. The next vertical passage of the reflected light beam initiates the reversal, and the maximum forward travel of the beam is read on the scale in revolutions of the motor shaft.

Although the relay operates in less than five milliseconds, allowance for this time is made by properly positioning the zero point on the scale. The zero is the position of the light beam when the relay has operated to accomplish the reversal.

The circuit diagram for the instrument is shown in **Fig. 4**. A rectifier tube supplies d-c power for the photocell, thyratron, and relay operation.

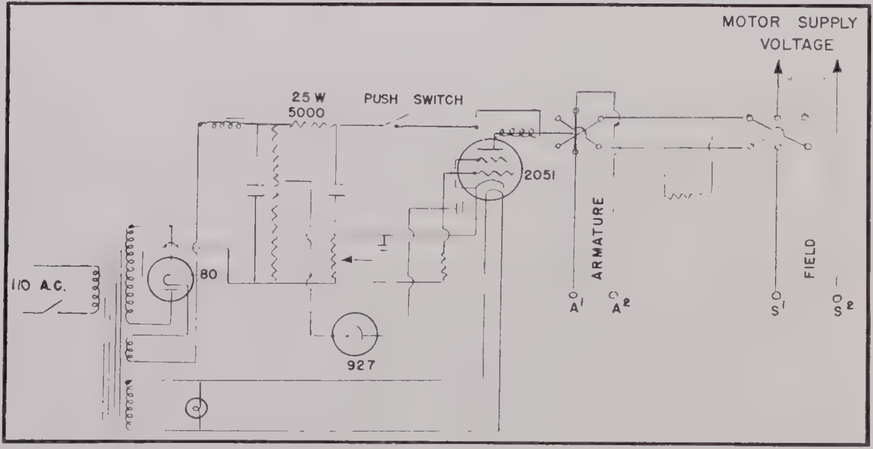

Fig. 4. Circuit diagram for the instrument shown in Figs. 2 and 3

For Reduction Gear Clutch-brake Combination

Another type of aircraft motor presented even more exacting problems of measurement. This motor is equipped with both reduction gear and a clutch-brake combination on the output shaft.

No attempt is made to start and stop the motor armature. Instead, the armature runs continuously, and the output shaft is started and stopped very quickly by a clutch between the reduction gear box and shaft and a brake on the shaft. The output-shaft speed is about 500 rpm, and the brake will stop the shaft within about ten degrees of rotation after the brake is de-energized. This means that the shaft stops in about six milliseconds, only slightly more than the operating time of the relay mentioned previously. Since the testing device for this motor had to be free from mechanical variables of the same order as the quantity to be measured, the scheme of testing previously described would be unsatisfactory.

Coasting tests were to be made with little or no added inertia on the output shaft. The brake circuit is highly inductive, and the difficulty of making a mechanical contact interrupt the brake current at a known zero point at 500 rpm (within ½ deg or less) can be understood. These requirements pointed to the use of a photocell-operated electronic device having no mechanical variables.

A satisfactory design of photoelectronic switching unit was developed, and instruments utilizing these units were built for production use. **Fig. 5** shows the device with motor clamped in place for test. This instrument utilizes a light beam, reflected from a mirror on the motor shaft, to trigger the instantaneous electronic cut-off of the clutch-coil current and to indicate

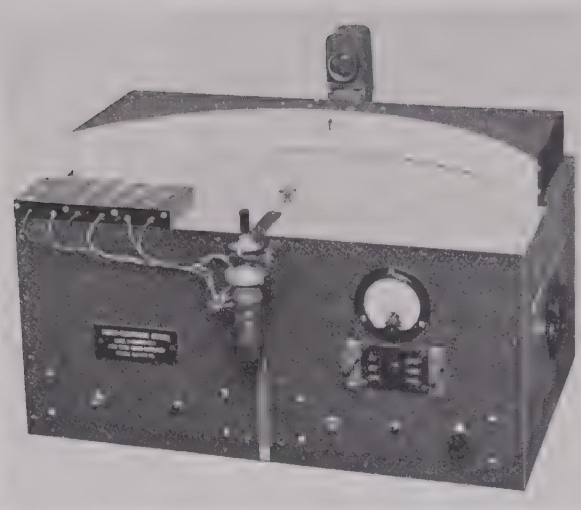

Fig. 5. Device for testing motor with reduction gear and clutch brake combination. The motor (*center*) is clamped to the case ready for test

the overtravel on a scale. The zero point is positive and unvariable; no load and negligible inertia are added to the motor shaft.

The coast angle is read without correction on the scale, which is calibrated in degrees of the shaft, with allowance for the doubling action of the mirror. Coast of 25 degrees in either direction of rotation is shown on the scale.

The use of vacuum tubes, with their high internal resistance, in the 30-volt clutch-coil circuit requires the use of a 230- to 300-volt d-c power supply. A 115-volt a-c operated unit supplies this power. For maximum safety in operation, one end of the clutch coil is held at ground potential. A 230-volt d-c factory supply source could be used in place of the rectifier unit, provided the supply is ungrounded, or the ground point in the circuit is moved to agree with the grounded supply line.

The power supply and switching unit are mounted side by side in a cabinet with control panels at the front. On top of the box are motor connection blocks, motor mounting fixture, light source, photocell, and scale. The switching unit includes the photocell, one amplifier tube, amplifier power pack with one tube, one thyratron, and four clutch-current-carrying tubes in parallel.

By the parallel arrangement, easily obtainable receiver-type tubes are used to carry a maximum of 400 ma clutch current. **Fig. 6** shows the internal arrangement.

Switches on the front panel control the motor armature and field, as well as the clutch-coil switching circuit. The circuit diagram is shown in **Fig. 7**.

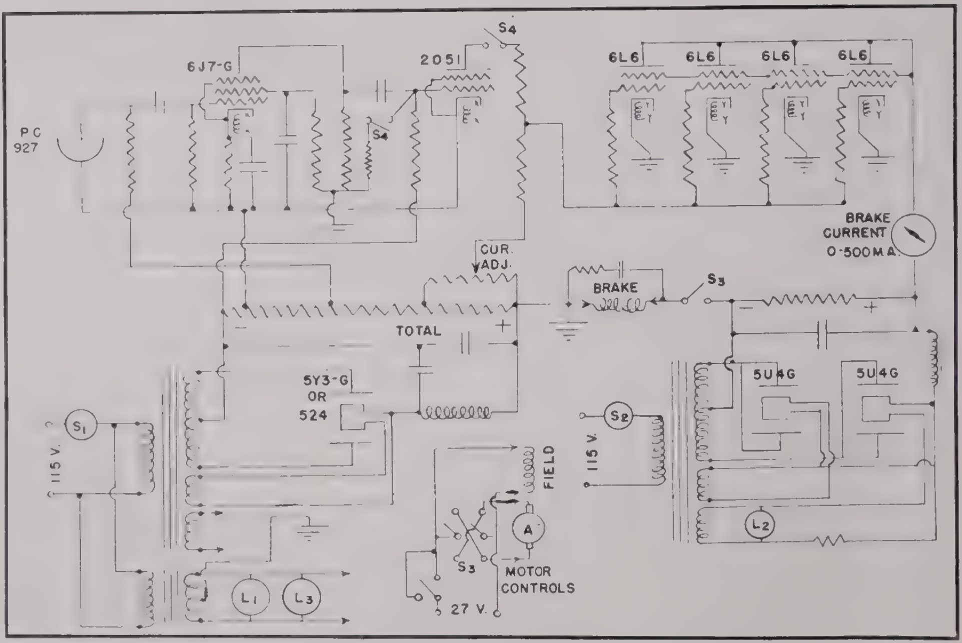

Fig. 7. Circuit diagram for the instrument shown in Figs. 5 and 6

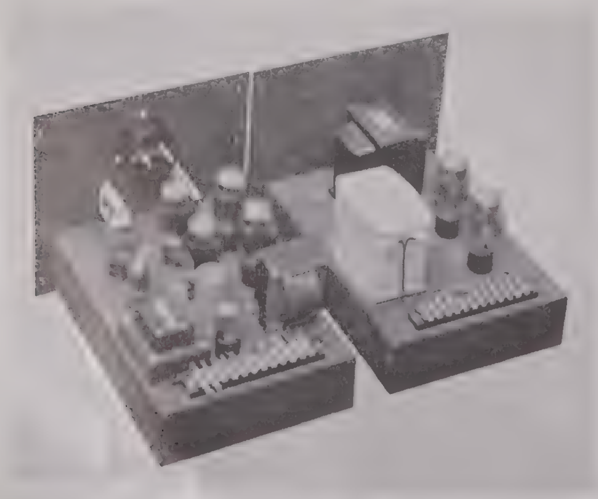

Fig. 6 Internal arrangement of power supply and switching unit

The switching operation may be described briefly as follows: The first light impulse following the closing of the thyratron-plate-circuit switch passes through the amplifier stage and fires the thyratron. The firing of the thyratron increases the negative bias on the 6L6 tubes from the small value needed to hold the clutch-coil current at the desired value to about 150 volts negative, causing complete cutoff. The clutch-coil current drops instantly to zero and the output shaft stops, with position of the light beam on the scale indicating the amount of coast. The shaft restarts about as quickly as it stops, and thus a large number of readings may be mentally averaged in a few seconds by operating the control switch rapidly.

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MODERN ELECTRIC EQUIPMENT FOR COLD-STRIP REDUCTION MILLS

Analysis of the exacting requirements of motors and control for modern high-speed tandem mills

William E. Miller

By W. E. MILLER
Industrial Engineering Divisions
General Electric Company

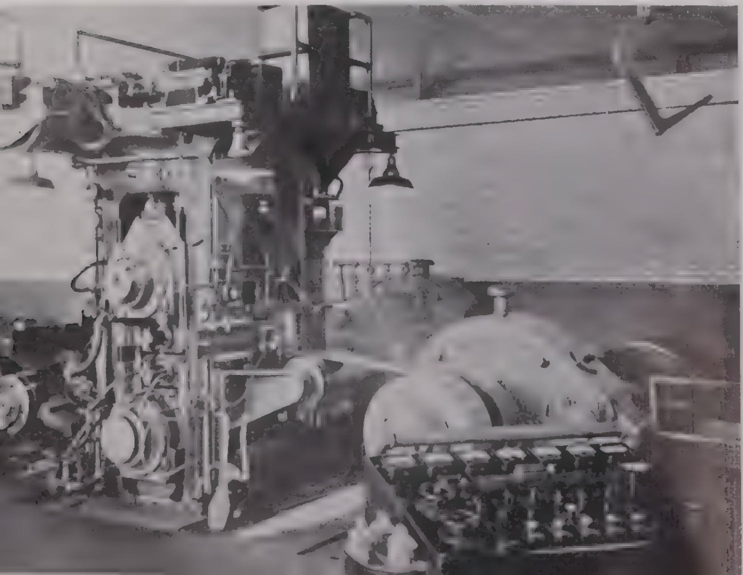
THE cold rolling of steel strip is a process that has been actively practiced now for over a half century. Fifteen years ago, the three fastest cold mills had delivery speeds of 800 fpm. Two of these high-speed mills of 1933 were single-stand reversing mills; the other, a narrow-width tandem mill.

Changes in mill equipment and electric equipment since 1933 have been noteworthy. Present-day reversing cold-strip mills operate with delivery speeds up to approximately 2000 fpm. Tandem cold-strip mills recently placed in operation in the Pittsburgh area have been operated at delivery speeds in excess of 5000 fpm. One of these mills which has electric equipment of the type described in this article has been operated successfully at speeds in excess of 6000 fpm. The engineering problems encountered in the design of the electric control system for a modern high-speed tandem mill are as interesting and as intricate as those encountered in any field of engineering. Not only must the system be designed for exacting steady-state operating conditions, but it must have a high speed of response for operation under transient conditions.

Types of Mills

However, before it can be shown how the engineering problems have been solved, it is necessary to have an understanding of how steel is rolled, and the problems which arise in obtaining a uniform high-quality product. Most modern cold-strip reduction mills are either four-high reversing mills or four-high tandem mills. There are, of course, other types of mills, but they have rather special characteristics and will not be considered here. The reversing mill and the tandem mill each has its own respective field of application, with some degree of overlapping between the fields.

Fig. 1. A typical reversing cold-strip mill



In the modern arrangement of these mills, both receive metal strip of uniform width and thickness in coil form, reduce the thickness or gage a certain amount, impart certain physical qualities to the product, and deliver the product in coil form.

The reversing mill (**Fig. 1**) consists of a single-roll stand, with a tension reel on each side of the roll stand. Both the mill rolls and the reels are motor driven and arranged for reversible operation. To effect the required reduction, the strip is passed back and forth through the single set of rolls for the necessary number of passes, the screws being reset between passes.

The tandem or continuous mill (**Fig. 2**) consists of from three to five roll stands and a tension reel arranged in a continuous line, so that the strip passes successively through the several roll stands and is coiled under tension as delivered from the last stand.

As to field of application, the reversing mill has been considered adaptable to a relatively moderate production of several types of products, while the tandem mill, in general, has been considered to be a high-production, single-purpose unit. Thus it is that tandem mills are usually designated as tinplate mills or sheet mills. However, a tinplate mill is generally laid out so that sheet can be rolled, and a sheet mill can be made capable of rolling tin plate with two passes through the mill. Such great changes in rolling schedules are made with a reduction in efficiency in the use of the mill. It has been said that the reversing mill stresses flexibility and that the tandem mill stresses production.

Both types of mills are driven by d-c motors supplied from adjustable-voltage motor-generator sets. A few years ago, it was general practice on both types of mills to supply all d-c motors from a common bus, with one or more d-c generators supplying power to the bus. Speed adjustments between stands or on the reels were made by motor field control. It has been recent practice on reversing mills to supply power to the stand motor and reel motors from separate generators and not from a common bus. On most high-speed tandem mills

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Presented as a paper by the author at the AIEE Winter General Meeting, January 26–30, 1948, at Pittsburgh (Pa.). —Ed.

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now in service, all the d-c motors are supplied from a common bus. Adjustment of individual stand and reel speeds is by motor field control, and on some mills installed in recent years by so-called *IR* compensation line boosters in series with the stand and reel motor armature circuits. Such a scheme for a tandem mill is shown in **Fig. 3**. An explanation of *IR* compensation and of a newer scheme including *IR* compensation, but without the series line boosters, will be given later.

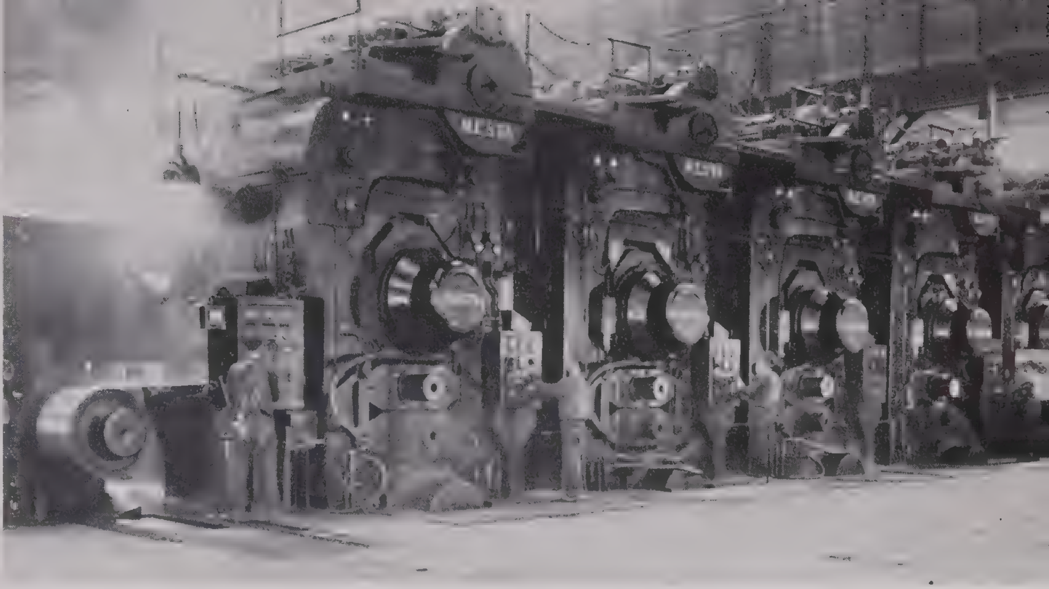
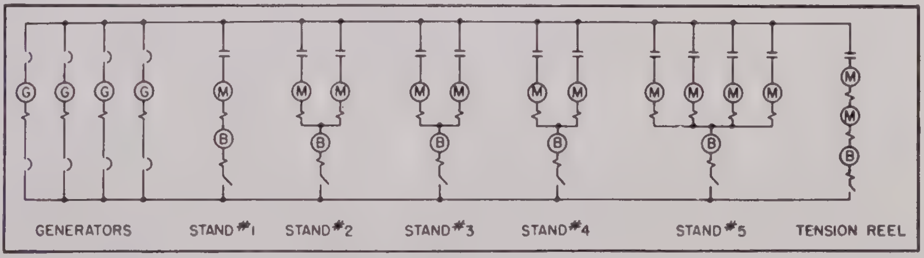


Fig. 2. A typical five-stand tandem cold tinplate mill

Problems in Rolling Cold Strip

In tandem cold-strip mills of the modern high-speed type, the hot-rolled strip coil is threaded into the entering end of the cold mill with the finishing end operating at speeds of 100 to 600 fpm. During or after the threading of the delivery tension reel, the mill may be accelerated to a top speed of from 4000 to 5000 fpm, or, on mills now going into service, even higher. After rolling most of the coil at top speed, the mill is decelerated to threading speed as the tail end of the strip is approached. It is the desire of the operator to have the strip "on gage" at all times, or, failing in this, to get "on gage" as soon as possible while the mill is accelerating and to stay "on gage" as long as possible while the mill is decelerating.

Fig. 3. Armature circuit connections for a five-stand tandem tinplate mill with generators connected to a common bus and using series boosters for *IR* compensation. Dynamic-braking resistors and contactors are not shown. Total motor capacity represented in this diagram is 16,850 hp



There are several factors involving the working of the metal during rolling, and the balancing of stand-motor constants which materially affect the strip gage during periods of acceleration and deceleration. Tests have been made which demonstrate conclusively, even on a single-stand mill, that the gage will be heavier at low speeds than at high speeds, and heavier with low tensions than with high tensions, if all other factors remain constant. Just why the gage goes heavy at low speeds is not completely understood, but electric means of control can be used to compensate for the effect in spite of the obscure cause.

If moments of inertia (motor plus mill) are properly balanced between stands, each motor will require the same per cent current for acceleration. If, in addition, the per cent rolling load on all stands is the same, and if the per cent rated speed regulation is the same, and if the per cent operating speed of all motors is the same, then, as the mill is accelerated and decelerated, all motors will remain in speed correspondence. If a variety of products is to be rolled on a mill, the flexibility of adjustment required between stands by motor field control alone is such that all the conditions given are not satisfied. Practical limitations in motor and mill design also limit the extent to which it is possible to balance the moments of inertia.

It will generally be found that the per cent accelerating current required for a given set of conditions will increase from the first to the last stand. Thus, during periods of acceleration and deceleration, there will be a loss of speed correspondence between stands. For example, during acceleration the last stand will tend to accelerate more slowly than the stand preceding it, and it can be seen that there will be a decrease in tension. When all motors are up to speed, tensions will be normal. During deceleration, the last stand will tend to slow down at a lower rate than the stand preceding it, causing an increase in tension between stands. Thus, because of normal mill inertia effects alone, the mill will tend to go from "heavy" to "on gage" as the mill is accelerated, and from "on gage" to "light" as the mill is decelerated.

The combination of the low-speed effect and the effect of mill inertia on tension helps to explain some of the many tendencies that make it harder to get on gage during acceleration than to keep on gage during deceleration. As the operating speeds of mills are increased, the tonnage of material rolled during the accelerating and decelerating periods increases, and the importance of getting the mill on gage during the early part of the accelerating period becomes more important. On new high-speed tandem mills, coils weighing 30,000 lb are being used. If such a coil is 32 in. in width and is finished to 0.0091 in., its length will be 30,700 ft. If it takes six seconds to accelerate the mill from a threading speed of 500 fpm to a running speed of 5000 fpm, a total of 275 ft of strip will be delivered from the mill. The same amount of strip will also be delivered during deceleration to threading speed. Reduction of the percentage of this material that is off gauge during acceleration and deceleration can be obtained by electric means through proper selection and design of mill motors and control.

Selection of Electric Equipment

Before the motors and control for a cold-strip mill can be selected, certain mill data must be obtained and studied. First, it is necessary to know the type of material to be rolled and the tonnage required. Since the maximum reduction per stand is limited, the type of product more or less determines the number of mill stands. Sheet mills usually consist of three or four stands while most tinplate mills consist of five stands. Rolling schedules for the various products must be worked out and rolling speeds obtained. The selection of the motors depends directly upon the rolling schedules for which the mill is designed.

The method most commonly used to calculate the loads which will be imposed upon the driving motors of a proposed mill, when rolling a particular product at a specified rolling speed with a specified reduction in each stand, makes use of test data obtained from the operation of other mills of the same type. To make the test data generally applicable, it is reduced to the basis of energy units per unit of rolling work and plotted against reduction in curve form. A typical curve for mild steel such as forms the great bulk of strip tonnage is shown in **Fig. 4**. Use of the curve is demonstrated in Table I, where a set of calculations for a rolling schedule is given.

Another method sometimes used in the calculation of rolling-power requirements is to figure the rolling pressure by one of the methods using basic resistance to compression, and from the pressure and the lever arm and speed calculate the rolling power. However, when rolling-power curves are available, their use is generally preferred, being based on accurate electrical data.

Table I: POWER CALCULATIONS

Rolling 32 in. wide by 0.095 in. thick mild strip to 32 in. wide by 0.0091 in. thick; 5 passes—4500 fpm

1. Pass number		1		2		3		4		5		Reel	Total
2. Strip thickness	0.095		0.057		0.034		0.020		0.0125		0.0091	.	
3. Strip cross section	3.04		1.82		1.09		0.64		0.40		0.291	.	
4. Per cent reduction		40		40.5		41		37.5		27			90.4
5. Total elongation	1.00		1.67		2.80		4.75		7.60		10.4	.	
6. Strip fpm	430		720		1210		2045		3295		4500	.	
7. Net tons per hour		133.5		133.5		133.5		133.5		133.5			133.5
8. Hp-hr per ton													
(a) Total (from curve, **Fig. 4**)			18.5		43		71		99		119		
(b) Per pass		18.5		24.5		28		28		20		...	119
9. Net rolling hp		2470		3300		3740		3740		2670		...	15,940
10. Strip tension													
(a) Per square inch			18,000		20,000		28,000		40,000		8000	. .	
(b) Total			32,800		21,800		17,900		16,000		2330	.	
11. Tension hp			720		800		1110		1600		320	...	
12. Net motor hp		1750		3220		3430		3250		3950		320	15,920

$\text{Net tons per hr} = \frac{(\text{Area in square inches}) \times \text{fpm}}{9.82}$ Net rolling hp = Net tons per hour × hp-hr per ton per pass $\text{Tension hp} = \frac{\text{Total tension} \times \text{strip fpm}}{33{,}000}$

Table II: Wk^2 AND PER CENT ACCELERATING CURRENT

Five-stand tandem tin-plate mill

Stand	Total hp	No. of Arm's.	Type of Drive	Motor rpm	Gear ratio	Wk^2 in lb-ft^2 at motor shaft × 1000			Per cent Amperes to Accelerate Mill and Motors*	Per cent Amperes to Accelerate Motors Only*
						Motor	External	Total		
1	1750	1	SA	80/240	1:1	123	38.5	161.5	33.0	25.0
2	3500	2	DA	150/360	1:1	100	38.5	138.5	31.8	23.0
3	3500	2	SA-T	175/350	1:1.525	74	96.2	170.2	36.9	15.6
4	3500	2	SA-T	200/400	1:2	66	192.0	258.0	73.0	18.7
5	4000	4	DA-T	275/535	1:2	36	192.0	228.0	101.0	15.9
Reel	600	2	DA	300/1200	1:1	3.1	3.6	6.7	99.5	46.0

SA—Single Armature DA —Double Armature SA-T—Single Armature, twin drive DA-T—Double Armature, twin drive

* Acceleration in 10 sec from rest to top rated speed with weak field setting on each motor.

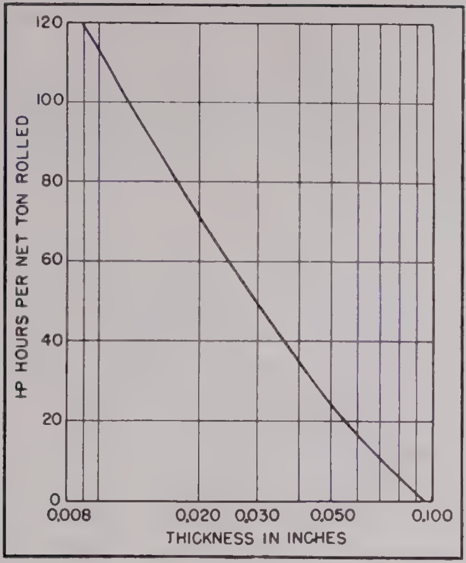


Fig. 4. Typical power curve for cold-rolling strip steel on a five-stand tandem mill from 0.095 in. to 0.0091 in. thickness. (Mild open-hearth steel)

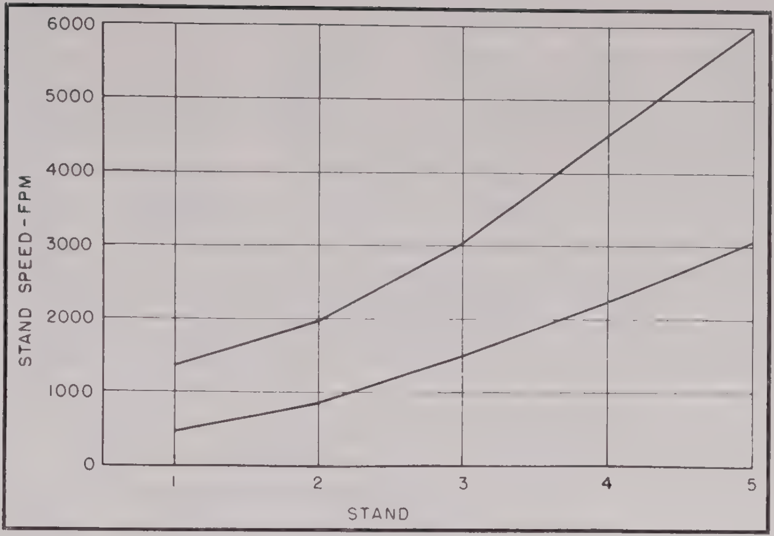


Fig. 5. Typical speed cone for a five-stand tandem tinplate mill

A typical set of power calculations for one schedule on a five-stand tandem tinplate mill is shown in Table I. A set of such calculations must be made for every schedule. Motor horsepower selection should be based on the heavier schedules. Strip speed through the mill and strip width do not seem to affect power consumption per ton of product in the usual operating range.

Motor Selection

A study of the set of rolling-schedule calculations for the mill will permit the selection of motor-horsepower ratings and speed-range requirements for each stand. It is usual practice to plot the stand speeds for each rolling schedule. The maximum and minimum speeds required for each stand determine the speed range required of that stand motor. A plot of maximum and minimum speeds for each mill stand gives the so-called "speed cone." A typical speed cone for a five-stand tandem mill is shown in **Fig. 5**.

It may be found that some infrequent schedules will require motor-horsepower ratings slightly above those required by the heaviest normal schedule. Rather than increasing the size of the motors and penalizing the operation of the mill during acceleration and deceleration on the normal schedules, it is present-day practice to provide mill-stand power units with full Class B insulation and to rate them on a 40C continuous basis with forced ventilation. Such a rating will allow the machines to carry a 20 per cent overload continuously without injurious heating, and should provide the margin necessary to take care of the infrequent schedules and permit rolling some of the normal and lighter schedules at higher speeds at some future date.

The selection of the motor-horsepower rating and speed range for each stand does not completely specify that motor. Actual motor speed, peak rating, and type of drive also must be given. These quantities should be selected on the basis of keeping the stored energies as low as possible and maintaining as near a balance as possible between stands. The peak rating of the motor is dependent upon the total Wk^2, since the mill must be accelerated carrying full rolling load plus the power required to accelerate the motor and the mill.

Since it is the effect of the Wk^2 on the electrical system which is of concern, Wk^2 for each stand must be obtained referred to the stand-motor shaft. The Wk^2 of the stand motor shaft will be affected by three factors: motor Wk^2; gear ratio; and mill Wk^2. There are various drive arrangements which may be used. The simplest form consists of a single-armature motor driving the mill through a pinion stand of 1:1 ratio. Double-armature motors may also be used with this arrangement. In addition to reduction of Wk^2, additional advantages are obtained through the use of so-called twin-drive motors where each roll is driven by a separate motor. Here, again, it may be necessary to use double-armature motors, thus having a double-armature twin-drive motor with four separate armatures.

Since the speed of the material increases as it goes through the various stands, it is necessary to either use higher-speed motors at the finishing end or to use speed-increasing gears of increasing gear ratio on the finishing stands. On low-speed mills, speed-decreasing gears may be used on the entering end stands. When referred to the motor shaft through speed-increasing gears, the mill Wk^2 will be increased by the square of the gear ratio. Thus, although the mill external Wk^2 may be the same on every stand, the effective mill Wk^2 (referred to motor shaft) increases from the entering stand to the finishing stand. If any attempt is to be made to balance the kinetic energies, it thus becomes necessary to reduce the motor Wk^2's on the finishing end of the mill by increasing the number of armatures used. Thus, it will be found on large mills that the first stand may consist of a single-armature motor driving through a 1:1 pinion stand, while the fifth stand may consist of a double-armature twin-drive motor with four armatures driving through speed-increasing gears.

Table II shows the Wk^2 of the stand motors, the Wk^2 of the mill, and the per cent accelerating current to accelerate the motor only, and the per cent accelerating current to accelerate both motor and mill for a typical five-stand tandem mill. The per cent accelerating current, for convenience, is based upon accelerating from zero to maximum speed in ten seconds.

While it has been said that the per cent accelerating current should be equal on each stand, Table II shows that this has not been accomplished. The Wk^2 and the kinetic energy could be increased artificially on the stands at the entering end of the mill, but such a procedure would certainly be undesirable. A study of Table II indicates that the kinetic energies of the last stands cannot be materially reduced by changing the motors, because the greater part of this energy is in the mill itself. For instance, to achieve any reduction on stand No. 5, it would probably be necessary to go to eight armatures, each rated 500 hp. Such an arrangement would make the motors and also the control cost considerably more. Thus, it will usually be found that, on large mills, the per cent current to accelerate the mill and motors increases from the entering to the finishing end of the mill.

Where cold-strip mills operate at very high delivery speeds, it becomes very important to keep the peripheral speed of the upper and lower working rolls the same at all times. On the finishing end of a mill rolling thin gages, there is considerable pressure between rolls, even with no metal in the mill. With any difference in working roll diameters on a pinion-driven mill, this would make the rolls grind each other and cause their surfaces to become rough. This is avoided with separate roll drives or twin drives, which permit the rolls to be operated at slightly different angular speeds.

Generator Selection

Selection of the generators to supply d-c power to the mill motors is dependent upon both the mill motor horsepower ratings and the control scheme to be used. As the state of the art of cold rolling has advanced, the higher and higher mill delivery speeds have raised the power requirements to the point where it is necessary to use almost as many generators on the bus as there are mill stands. The flexibility of the tandem mill can be increased if the number of generators is equal to the number of mill stands, and the main bus is broken so that a separate generator then supplies the motor driving each stand. Adjustments between mill stands can then be made by generator voltage control as well as by motor field control. Thus, the speed range of each stand is widened at the lower end by reducing the horsepower output. In addition, the IR-compensation function can be included in each stand generator regulating circuit, and the bothersome series boosters can be eliminated.

It has been found that, where large amounts of power are required, the most economical generator rating is about 4000 kw. For the five-stand tandem mill being considered, the total horsepower is 16,850. Three large generators might be used to supply d-c power to the motors. In addition, a fair-size booster generator would be required for the reel circuit. Since three large generators and one large reel booster will be required on the common-bus scheme, the advantages are definitely in favor of the individual-generator scheme, which requires two additional generators, but permits the omission of all the high-current IR-compensation boosters, the purpose of which will be explained later. The generators selected are given in Table III, and are arranged in two motor-generator sets.

Since it is necessary that the generators be able to handle any loads which the motors will carry, even when taking into account the 20 per cent overload capacity sometimes incorporated in the motors, the generators must also be completely insulated with Class B materials. Both motors and generators are rated 600–750 volts d-c in order to have line currents at the lowest possible level without encountering complications associated with higher voltages.

TABLE III: **MAIN GENERATOR RATINGS**
Five-stand tandem tin plate mill

M-G Set No.	Stand No.	Generator kw rating	Generator Voltage
1	1	1500	750
1	2	3000	750
1	3	3000	750
2	4	3000	750
2	5	3200	750
2	Reel	500	750

Selection of Control

The majority of the up-to-date tandem mills now in service are equipped with separate d-c motors on each stand, supplied as a group with d-c power from an individual generator, or a group of generators connected to a common bus and operating as a unit. The majority of the high-speed high-power tandem mills now going into service differ in that an individual generator supplies power to each stand motor. Armature circuit connections for the individual-generator scheme are shown in **Fig. 6**.

The choice of the basic control scheme is a matter of economics. Certainly, on a high-speed high-power mill, the advantages of the individual-generator scheme are many. First, the high-current series booster generators and their control are eliminated. Second, the heavily supported high-current bus is eliminated. Third, and most important, is that each generator may, if desired, be operated at a different voltage.

On a high-speed tandem mill, electric gage control during the mill accelerating and decelerating periods is a "must." Gage control can be obtained during these periods if the mill motor speeds are changed in such a way as to automatically adjust the strip tension between stands. There are two general methods of control. The first is by automatic control of the shunt-field strength of one or more of the stand motors, the method being called "tapered-tension control by motor field

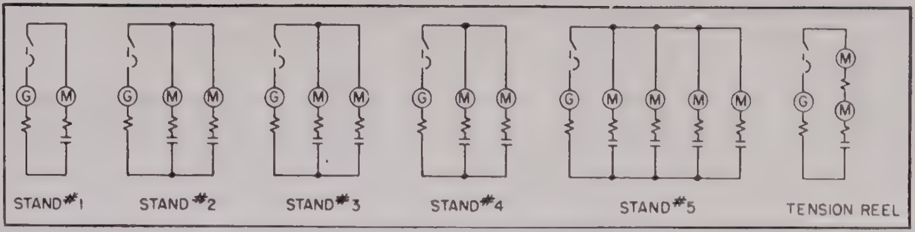


Fig. 6. Armature circuit connections for a five-stand tandem tinplate mill with individual generator for each stand and *IR* compensation included in regulating control system. Dynamic-braking resistors and contactors are not shown. Total motor capacity is 16,850 hp

adjustment." The second is by an independent control of motor armature voltage by an amount equal to the *IR* drop in the system, or a part of it, the method being called "*IR*-drop compensation." In the past, where *IR* compensation has been provided, it has been general practice to use the series booster generators for this purpose. On new mills with the individual-generator scheme of control, the series booster generators are eliminated and the *IR*-compensation function is included in the regulating control system.

While both tapered-tension control and *IR* compensation make it possible to get on gage sooner as the mill is accelerated and to stay on gage longer as the mill is decelerated, the *IR*-drop-compensation method is more nearly automatic than is the tapered-tension method. With *IR*-drop compensation, the motors more nearly "sense" gage and automatically taper the tensions as needed. With tapered-tension control, it is necessary that the tapered-tension rheostats be set in advance. Thus it is that *IR*-drop compensation seems to be the preferred method of electric gage control in the ultra-high-speed rolling of cold strip. Tapered-tension control or *IR*-drop compensation may or may not be considered necessary on lower-speed mills.

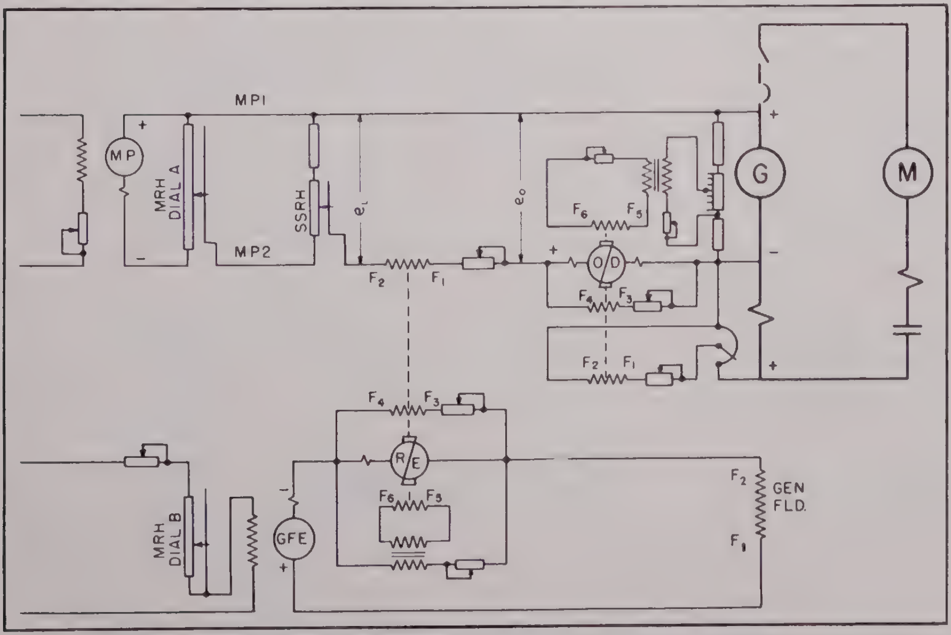


Fig. 7. Amplidyne-type voltage regulating control circuit, showing ohmic-drop compensation and stabilizing circuits for one stand of a five-stand tinplate mill using an individual generator for each stand

The strip, after being rolled, is reeled into coils. Control must be provided which will automatically maintain constant tension in the strip as it is being reeled, and also automatically provide for the change in motor speed required by the reel build-up. Since the strip will be delivered from the last mill stand at constant speed, and since it is desired to hold constant tension, a regulator is required which will give a constant-horsepower characteristic. Such control can be provided by a regulating tensiometer measuring tension directly or by a current regulator maintaining constant reel-motor-armature current by changing the shunt-field excitation of the reel motor.

The majority of the tension regulators now in service are of the current-regulating type. The use of this type of tension regulator is based upon the maintenance of constant reel-motor-armature voltages. Thus, reel build-up must be taken care of entirely by field control. On modern high-speed mills, coils must be large to make the full-speed running time a reasonable period. Thus, the speed range required for reel build-up may be large and becomes a limiting factor in the design of the reel motor.

With the tensiometer type of tension regulator, automatic adjustments to hold constant tension may be made by changing both motor armature voltage and motor-field excitation. Thus, where the coil build-up is large and permissible speed range by field control is a limiting factor, use of a tensiometer type of regulator will permit the use of a more nearly normal reel motor.

Control Circuits

The control circuit for the individual-generator scheme for a single stand is shown in **Fig. 7**. It is seen that the mill master rheostat determines the voltage on the master voltage-control bus *MP1* and *MP2*. This bus is the standard by which the voltage on every generator is controlled. By raising or lowering the voltage on this bus, it is possible to raise or lower (proportionately) the voltages of all the generators. The mill master rheostat also controls the excitation on the generator-field exciter *GFE* which supplies all stand generators. In this way, regulating exciters *RE* on each stand can operate at low voltage levels ideal for fast regulator action.

Individual voltage adjustment on each generator can be accomplished by movement of the stand master rheostat. Each stand-motor speed can also be controlled by adjustment of its shunt-field current. However, regardless of the settings on the stand master rheostats, the mill master rheostat will raise or lower each generator voltage proportionately.

It has already been pointed out that it is usually desirable not only so to control all generator voltages that they are proportional to the voltage on the master voltage-control bus, but also to compensate for *IR* drop in all motor-armature circuits. In this way, the speeds of all motors may be held closely proportional to the voltage on the master voltage bus. It can be seen in **Fig. 7** that the ohmic-drop exciter *OD* receives its excitation from the voltage drop across the generator commutating field, and its output voltage may be made equal to (or any fixed percentage of) the motor-armature-circuit *IR* drop. The voltage of this amplidyne is automatically subtracted from the generator terminal voltage. Each stand regulator, through its regulating exciter *RE*, then acts to hold essentially motor cemf which is directly proportional to motor speed.

The control circuit for a tension reel is shown in its simplified form (less stabilizing elements) in **Fig. 8**. The system shown includes a tension regulator of the current-regulating type. As already explained, this regulator acts to maintain constant reel-motor-armature current by changing the shunt-field excitation of the reel motor. The over-all control is so arranged that reel-generator voltage is proportional to strip speed, and reel build-up is taken care of by reel-motor field control. Reel-generator voltage is then a function of both last-stand generator voltage and motor-field weakening.

Selection of Circuit Constants for Optimum Performance

In no other type of rolling mill does the performance of the electric equipment affect the quality of the product to a greater extent than in the cold-strip mill. The accuracy of the gage, the ease of maneuvering, the mill tonnage, and the per cent yield all depend directly upon how well the electric-drive system is co-ordinated. Not only must the system be designed to operate over an extremely wide range of steady-state operating conditions, but it must be designed to have a high rate of response so that changes in operating conditions may be made quickly with all stands acting together.

Regulating circuits of the type shown in **Figs. 7** and **8** are also called servomechanisms. The study of such circuits has been both intensive and extensive during the past few years. Actual circuits have been tested to study transient performance in the laboratory, factory, and field. System studies have been made on differential and transient analyzers. Complete servomechanisms have also been analyzed by the frequency-response methods of Nyquist and Bode. By correlating the data available, it is possible to analyze the systems of **Figs. 7** and **8** by the frequency-response method, and to select the circuits and circuit constants which will give the desired system performance.

The complete amplidyne-type regulating control circuit for one stand of a five-stand tandem tinplate mill is shown in **Fig. 7**. The control for every other stand is identical. Two small-size identical transformers are used to obtain voltage rate-of-change signals for stabilization. The ohmic-drop exciter *OD* is also used as an amplifier for the voltage-rate-of-change signal fed back from the main generator *G*. The amplidyne exciter used for this application is ideally suited for its dual purpose because of its high gain and very low time constant. The time constant of amplidyne *OD*, as shown in **Fig. 7**, is less than 1/300 of the main-generator time constant.

The block diagram for the regulating system of **Fig. 7** is shown in **Fig. 9**. In constructing the diagram, it was assumed that the error introduced by considering the generator-voltage-feedback signal to be proportional to the rate of change of internal voltage instead of terminal voltage is small.

The basic method of analysis and the mathematical justification of the frequency-response method of analysis have been completely presented in available published literature. Briefly, it is necessary to apply an alternating input signal of constant magnitude and

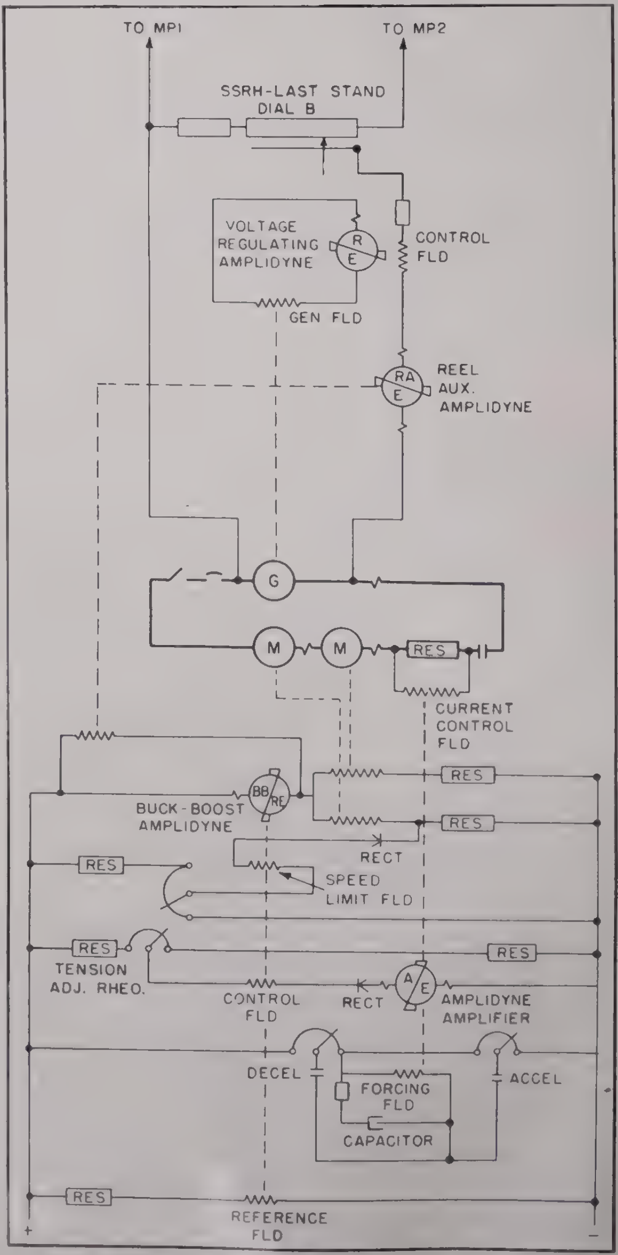


Fig. 8. Amplidyne-type regulating control circuit for tension reel on a tandem cold-strip mill, showing tension (current type) regulator and voltage regulator following reference set up by last mill stand

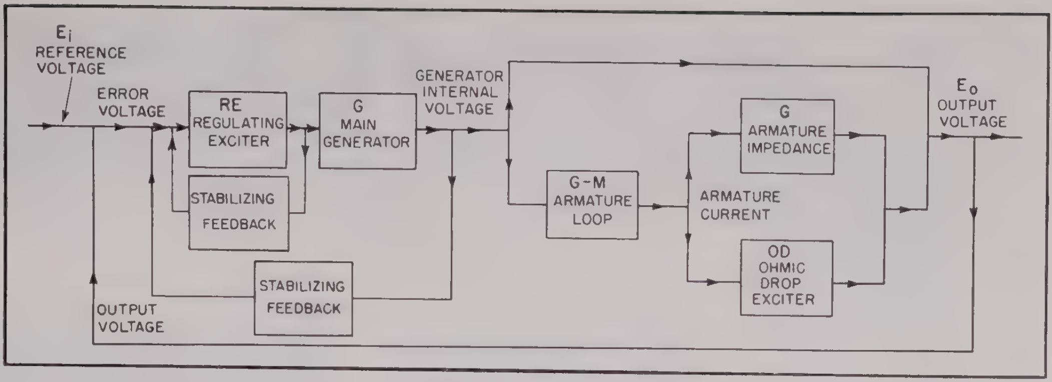


Fig. 9. Block diagram for amplidyne-type voltage regulator with *IR* compensation for one stand of a five-stand tandem cold-strip mill using individual generator for each stand. (The schematic control circuit is shown in Fig. 7.)

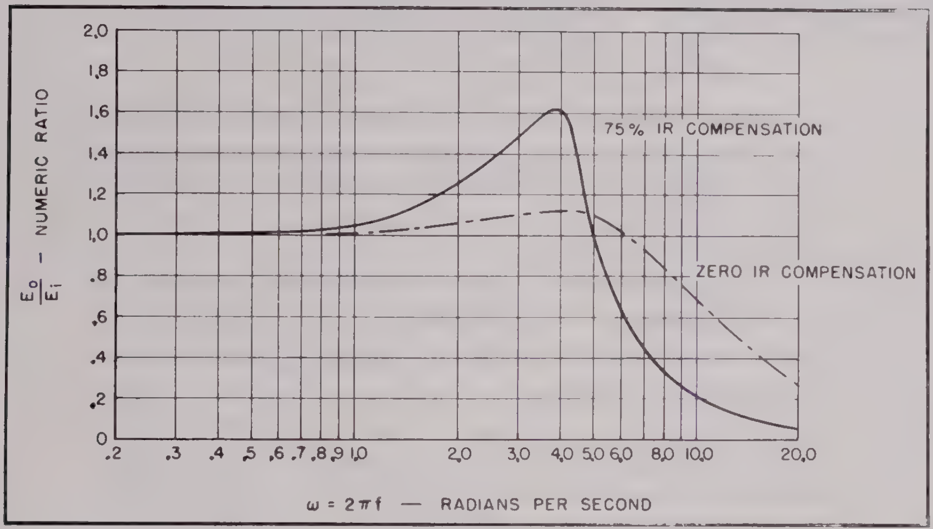


Fig. 10. Frequency response of voltage regulator with *IR* compensation for stand No. 5 of tandem tinplate mill (motor operating with weak field)

varying frequency to the input side of the system and to determine both the magnitude of the output signal and its phase relation with the input signal. The frequency response must be determined over the whole frequency spectrum of the system. To do this mathematically, it is usual practice to break the system up into its component parts, as shown in **Fig. 9**, and to determine the transfer function of each part. These transfer functions are then combined either mathematically or graphically to obtain the system transfer function and the system-frequency response. From a study of the frequency response and phase characteristics of the system components and the whole system, it is possible to select and adjust circuits so as to cause the system to have the desired transient characteristics.

Frequency-response curves for the system shown in **Fig. 7** are given in **Fig. 10**. It is seen that the effect of *IR* compensation is to increase the peak response of the system. However, with 75 per cent compensation, the peak is well within the limits recognized as required for good performance. Tests have been made and reported upon before the Association of Iron and Steel Engineers upon the advantages and disadvantages of *IR* compensation. A study of the results of these tests indicates that 75 per cent *IR* compensation is about the maximum amount which can be used to advantage on a system made up of modern mill-type motors and generators.

Recent Tandem Cold-strip Mill Installations

There are five tandem cold-strip mills now in service or soon to go into service which have electric equipment and individual-generator-control systems of the type described in this paper. Control systems on all five mills were designed using the frequency-response method of determining transient performance. Initial results have been gratifying in that the regulating systems have performed as predicted. The first mill was placed in service in October 1947, the second in December. It is expected that the fifth mill will be rolling steel in the Chicago area during the early summer. The first mill, located in the Pittsburgh area, has already set new records for speed of rolling, having been successfully operated at approximately 6200 fpm.

Mill operating and maintenance men are well satisfied with the individual-generator scheme of control for tandem mills. Increased flexibility in setting up rolling schedules through adjustment of stand-generator voltage, elimination of the high-current series *IR*-compensation boosters, and reduction of the current capacity of d-c buses are factors of such importance on the modern high-speed high-power tandem mills that it is felt that all future installations will be of this type. Amplidyne-type regulators designed for fast transient performance, in accordance with the latest circuit theory and extensive tests, promise to be the tool which will hold the stands together to form a finely co-ordinated mill capable of rolling a high-quality steel product.

References

H. W. Bode: *Network Analysis and Feedback Amplifier Design*, D. Van Nostrand Company, Inc., New York, 1945.

"Regeneration Theory," by H. Nyquist, *The Bell Technical Journal*, vol. 11, Jan. 1932, p. 126.

"Electrical Features of Modern Cold Roll Strip Mills," by A. F. Kenyon, *Iron and Steel Engineer*, vol. 11, March 1934, p. 113.

"Electrical Equipment for Cold Strip Rolling Mills," by A. S. Wallis, *BTH Activities*, vol. 15, Nov.-Dec., 1939, p. 227.

"Gage Control in Cold Rolling Strip Mill," by J. D. Campbell, *Iron and Steel Engineer*, vol. 20, Aug., 1943, p. 52.

A. C. Hall: *The Analysis and Synthesis of Linear Servomechanisms*, Technology Press, Massachusetts Institute of Technology, Cambridge (Mass.), 1943.

L. A. MacColl: *Fundamental Theory of Servomechanisms*, D. Van Nostrand Company, Inc., New York (N. Y.), 1945.

"Parallel Circuits in Servomechanisms," by H. Tyler Marcy, *AIEE Transactions*, vol. 65, 1946, Aug.-Sept., Section, 521.

"Reversing and Tandem Cold Mills," by M. D. Stone, *Iron and Steel Engineer*, vol. 24, May, 1947, p. 65.

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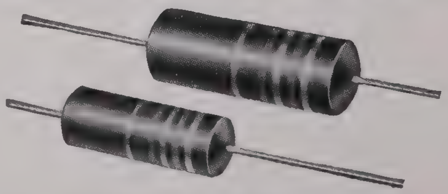

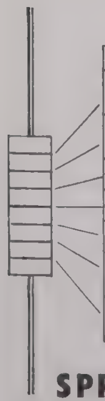

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			Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
1st BAND	Capacity in MMFD	First Significant Number	0	1	2	3	4	5	6	7	8	9
2nd BAND		Second Significant Number	0	1	2	3	4	5	6	7	8	9
3rd BAND		Decimal Multiplier			100	1000	10,000	100,000				
4th BAND	TOLERANCE		±20%			±30%	±40%	±5%				±10%
5th BAND	RESERVED FOR ARMED SERVICES											
6th BAND	Voltage in Hundreds (x 100)	First Significant Number	0	1	2	3	4	5	6	7	8	9
7th BAND		Second Significant Number	0	1	2	3	4	5	6	7	8	9

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HIGH-VOLTAGE RECTIFIER CIRCUITS . . . Part II

Single-way and double-way circuits that are generally used in high-voltage applications, and their voltage and current characteristics

By E. V. DeBLIEUX
Power Transformer Engineering Division
Pittsfield Works, General Electric Company

BECAUSE of the factors considered in Part I, few of the circuits used for power-rectifier application(3) are preferred circuits for high-voltage rectifiers; the single-way and double-way circuits considered here are those usually used in high-voltage applications. The voltage-multiplier circuits usually used will be presented later.

Table I shows the single-way and double-way circuits commonly used for high-voltage rectifiers. Table II gives voltage and current characteristics of the circuits shown in Table I.(a) The values given in Table II are based on the following assumed conditions:

(1). Sinewave primary voltages
(2). Load conditions as indicated in table
(3). No grid control
(4). No filter capacitors
(5). No inductance in a-c circuit
(6). Ideal rectifier (no arc drop or reverse current).

Voltage and current characteristics under other conditions will be taken up under the considerations of each circuit.

Half-wave Single-way

Circuit *1* (Tables I and II) is sometimes called the Villard circuit; its principal advantage is simplicity. The circuit requires only one rectifier tube and is used when low average value and large variations of the load voltage are permissible.

By the addition of a filter capacitor across the d-c terminals, the output voltage can be raised to a value approaching the peak a-c voltage. The larger the capacitor, the closer the output voltage approaches the peak a-c voltage.

In **Fig. 4** are shown the wave shapes obtained with various combinations of resistance, inductance, and capacitance in parallel in the load circuit. If the inductance and resistance are in series, the current wave shape will be as shown for I_L in **Fig. 4(b)**. If the capacitance and resistance are in series, the current wave shape will be as shown for I_C in **Fig. 4(a)**. In each case the load current is the sum of the branch currents. In this and any of the other circuits listed in Table I, the polarity of the load circuit with respect to the transformer terminal may be reversed by reversing the rectifier-tube connection.

If, in addition to the rectifier tube shown in Circuit *1* (Table I), a second rectifier tube is connected between the negative side of the load and the rectifier transformer winding, the inverse voltage is divided between two rectifier tubes. This circuit can then be used for voltages as high as double that permissible when one tube is used.

Unless the load resistance is high, compared with the rectifier resistance, regulation is poor and efficiency low. A maximum efficiency of 40.6 per cent is approached as the ratio of load to rectifier resistance becomes high. The fact that only one half of the a-c voltage wave is rectified is the major reason for the relatively low efficiency of this circuit.

Because of the poor transformer utility factor, the d-c component of current in the d-c winding, the resultant d-c flux in the core, the resultant increase in exciting current and input kva, and the high inverse voltage compared with the output voltage, this circuit is not attractive for power applications.(b)

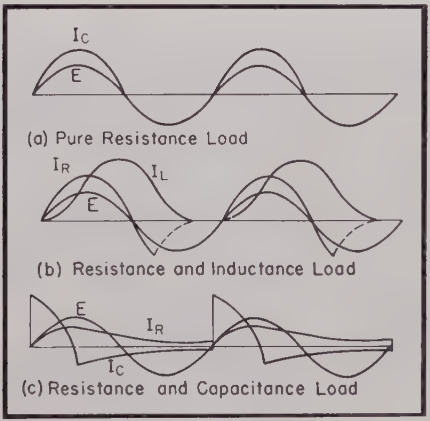

Fig. 4. Wave shapes obtained with various combinations of resistance, inductance, and capacitance in parallel in the load circuit

E = transformer secondary voltage
I_R = resistor current
I_L = inductance current
I_C = capacitor current

Diametric (Full-wave) Single-way

Circuit *2* (Tables I and II) is also called the Graetz or Midtap. **Fig. 5** shows that this circuit is composed

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This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 31 to 33.—ED.

(3) "Report on Proposed Standard for Pool Cathode Mercury-arc Power Converters," *AIEE No. 6*, June, 1946.

(a) "Methods for calculating the characteristics of the various single-way rectifier circuits shown in Table I can be found in:

"Characteristics, Design, and Applications of Rectifiers" by E. V. DeBlieux, GENERAL ELECTRIC REVIEW, Oct., Nov., and Dec., 1937, pp. 412, 481, and 539.

"Analysis of Rectifier Circuits" by E. F. Christensen, C. H. Willis and C. C. Herskind, *AIEE Trans.*, 1944, p. 1048.

Electrical Engineering Staff of MIT: *Applied Electronics*, John Wiley and Sons, Inc., New York.

(b) A method for calculating the characteristics of this circuit that takes into account the leakage reactance of the rectifier transformer is given in:

"Half-cycles," by D. W. Cockrell, GENERAL ELECTRIC REVIEW, Aug. 1935, p. 367.

Other references which give consideration to the wave shapes shown in Fig. 2 are:

Electrical Engineering Staff of MIT: *Applied Electronics*, John Wiley and Sons, Inc., New York.

"Half-wave Gas-rectifier Circuits" by C. M. Wallis, *Electronics*, Oct., 1938, p. 12.

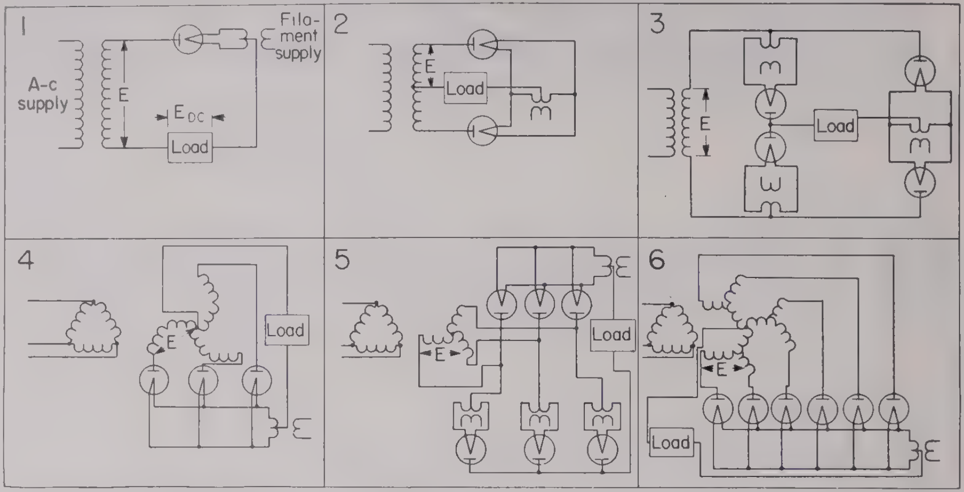
of two single-way half-wave circuits operating in parallel to supply a single load.

As compared with the half-wave single-way circuit in the preceding section, this circuit requires two tubes instead of one, but the direct current is twice, the power output four times, and the efficiency double that of the half-wave single-way circuit for the same peak current. And the output voltage is smoother, thus requiring a smaller filter.

For various combinations of resistance, inductance, and capacitance, the voltage and current wave shapes in the load circuit will, for each half-cycle, be similar to that shown for the first half-cycle in **Fig. 4.**[c]

TABLE I

SINGLE-WAY AND DOUBLE-WAY CIRCUITS USED FOR HIGH-VOLTAGE RECTIFIERS



The effects of the addition of a filter capacitor across the d-c terminals, and also of interchanging the tube connections, are the same as stated for Circuit *1*.

Diametric (Double-way) Bridge

Circuit *3* (Tables I and II) is usually called the Bridge circuit.

Compared with Circuit *2*, it will be noted that Circuit *3* requires twice as many tubes. Its output voltage (E_{avg}) is double that for Circuit *2*, yet the inverse voltage and the d-c output are the same. This circuit is therefore a means for doubling the output voltage obtainable without changing the duty of the tubes.

The center tap on the plate-supply transformer is omitted, and the entire winding of the transformer carries load current for the full cycle. The transformer is used to better advantage, and a smaller physical rating for the same output is required.

This circuit requires three filament transformers for the four tubes; the cost of the filament transformers will be somewhat more than double that required for Circuit *2*.

For Circuits *2* and *3*, the wave shape of the direct voltage is the same as that shown in **Fig. 5(b)**.

Three-phase Single-way

For application where the direct current is relatively large, it is essential that the d-c winding in Circuit *4*

TABLE II

CHARACTERISTICS OF SINGLE-WAY AND DOUBLE-WAY CIRCUITS

	D-c Winding			Rectifier Tube				
Circuit No.	E_{rms}	I_{rms}		E_{inv}	I_{avg}	I_{max}		Circuit Description
		Resistance Load	High-reactance Load			Resistance Load	High-reactance Load	
1	2.22G	1.57J	*	3.14G E_{Max}	J	3.14J	*	Half Wave Single Way
2	1.11G	0.785J	0.707J	3.14G $2E_{Max}$	0.5J	1.57J	J	Diametric (Full Wave) Single Way
3	1.11G	1.11J	J	1.57G E_{Max}	0.5J	1.57J	J	Diametric (Double Way) Bridge
4	0.855G	0.587J	0.577J	2.09G $\sqrt{3}\,E_{max}$	0.33J	1.21J	J	Delta Three Phase Wye Single Way
5	0.428G	0.817J	0.816J	1.048G $1.73E_{max}$	0.33J	1.048J	J	Delta Six Phase Wye Double Way
6	0.741G	Outer Wdg. 0.409J Inner Wdg. 0.578J	 0.408J 0.577J	2.09G $2.0E_{max}$	0.167J	1.048J	J	Delta Six Phase Star Single Way

J = D-c Current (Avg), G = D-c Voltage (No Load), $E_{max} = \sqrt{2}E$

* This circuit is inoperative with a high-reactance load.

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[c] For detailed consideration and circuit analysis, see:
Electrical Engineering Staff of MIT: *Applied Electronics*, John Wiley and Sons, Inc., New York.
"Full-wave Rectifier Analysis," by C. M. Wallis, *Electronics*, March, 1940, p. 19.

(Tables I and II) be connected zigzag, with the zig and zag that are on the same transformer leg closely coupled so that the d-c components of current in the zig and zag cancel.

If the ampere-turns per core leg are a small number, and particularly if a d-c component of flux in the core is permissible, the d-c winding may be connected in wye.

With the d-c winding connected in wye, the d-c component in each rectifier winding flows as a magnetizing current (equivalent to one third of the d-c output) and produces a d-c flux in the core legs.

If the transformer circuit consists of three single-phase transformers, and the d-c winding is connected in wye, the d-c component of flux in the core legs may be high and may produce saturation if combined with the a-c flux. An air gap in the core leg will reduce the magnitude of the d-c flux but will increase the a-c exciting current.

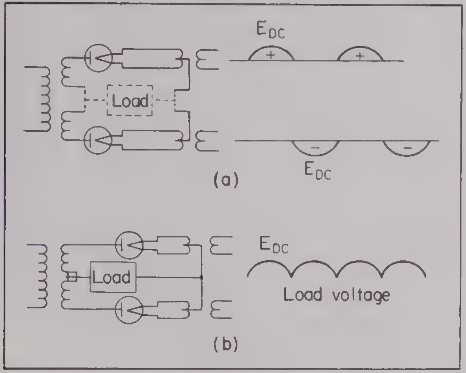

Fig. 5. Rectifier circuit and d-c wave shape for Circuit *2* (Table I): (a) two half-wave, single-way circuits supplying a common load; (b) diametric (full-wave) single-way circuit

If the transformer windings are connected in wye and are wound on a three-phase three-leg core, the d-c flux is in the same direction in all three legs and has to return through an external path. By magnetically insulating the transformer casing and clamps from the core, a gap is introduced in the path of the d-c flux path, but not in the a-c flux path.

Because of these characteristics, the wye-connected d-c winding is suitable only for applications where the direct current is of a relatively low value.

The polarity of the d-c terminals can be reversed by reversing the tube connection. It should be noted, however, that this requires the use of three separate filament transformers.

Six-phase Double-way

Circuit *5* (Tables I and II) requires twice as many tubes and a more complicated filament-transformer arrangement than does Circuit *4*.

The advantage of this circuit, compared with Circuit *4*, is that it gives a smoother output voltage without imposing more severe duty on the rectifier tubes.

If the connection of the d-c winding is changed from wye to delta, the operating characteristics remain unchanged. However, the number of turns in each d-c winding must be increased 73 per cent and the cross section of the conductor reduced a corresponding amount.

For very-high-voltage applications, a delta connection of the d-c winding is preferred to wye because of its greater stability. In general, wye connections of d-c windings with floating common or neutral points are not desirable because transients due to voltage surges and shifting of the common or neutral points may occur.(4)

Six-phase Single-way

Circuit *6* (Tables I and II) has the same number of tubes, the same output-voltage wave shape, and the same maximum tube current as Circuit *5*; but since each tube conducts for one sixth of a cycle, and in Circuit *5* each tube conducts for one third of a cycle (in pairs in series), the average and rms tube current of Circuit *6* for the same output current is only one half that of Circuit *5*.

An alternative connection to Circuit *6* is the d-c winding as a six-phase double-wye or a six-phase Fork (Star).(d)

For high-voltage applications, the connection shown in Table I is preferred for the reasons given in the consideration of single-way vs. double-way circuits.

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(4) "High-voltage, Steel-tank Mercury-arc Rectifier Equipment for Radio Transmitters" by J. C. Reed, Part II, *Jour. of IEE*, Oct., 1945, p. 453.

(d) A comparison of these three connections is given in:
"Characteristics, Design, and Applications of Rectifiers," by E. V. DeBlieux, GENERAL ELECTRIC REVIEW, Oct., Nov., and Dec., 1937, pp. 412, 481, and 539.

(*To be continued*)

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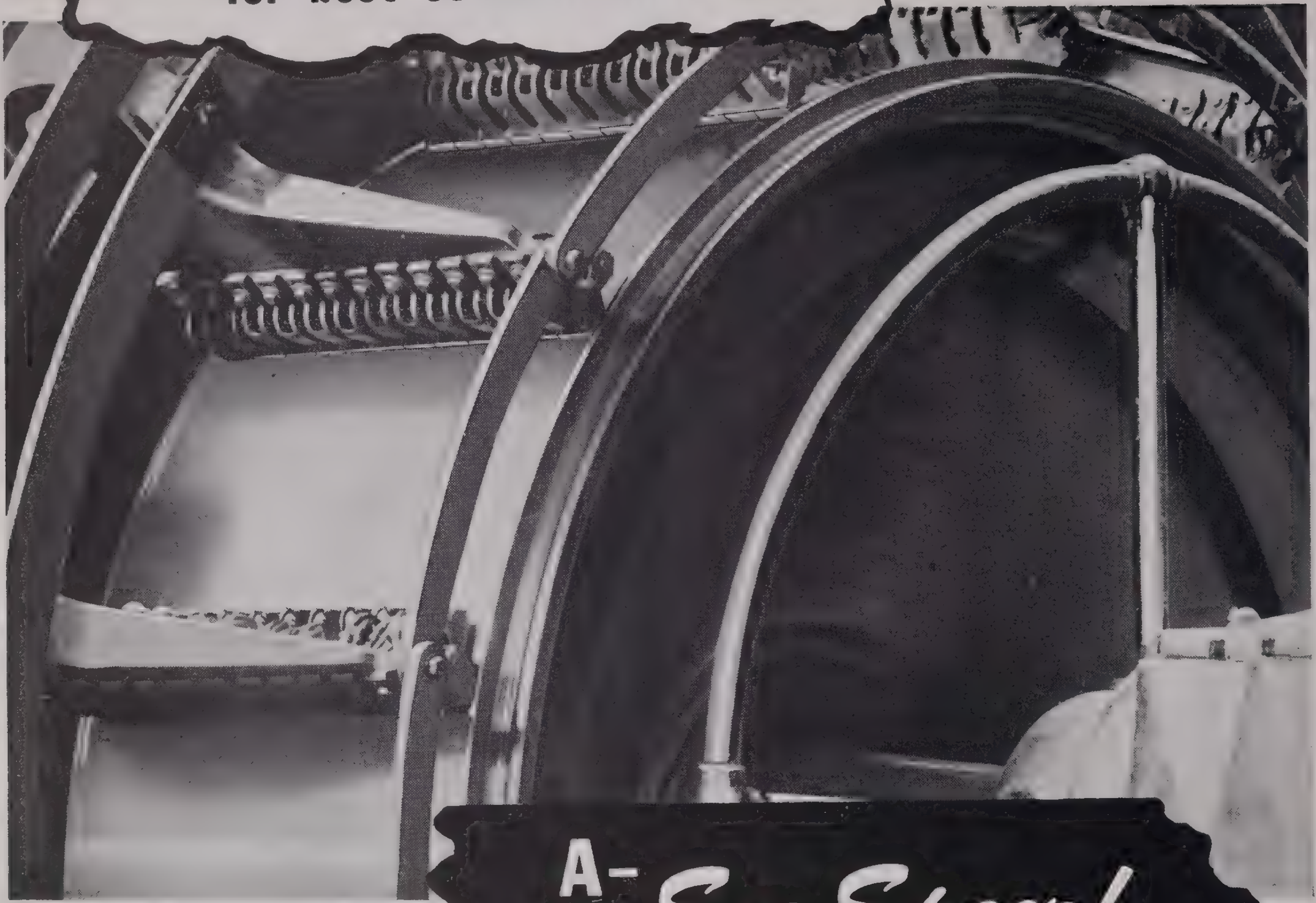

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MELTING METALS BY INDUCTION HEATING

With both the coreless-induction and submerged-resistor types. Operational data, electrical features, general construction, and applications

By N. R. STANSEL
Schenectady, N. Y.

N. R. Stansel

THE term *melting* includes, in addition to the change from the solid state to the liquid state, the further heating of the metal to some specified temperature. This temperature is known as the pouring temperature if the metal is to be poured into molds, or as the working temperature if the metal is to be used for coating, as in galvanizing, or as a liquid heating bath—for example, the lead bath for heating steel parts for hardening.

Refining a metal or alloy may follow melting. The term denotes the removal of impurities from the molten metal before it is poured. The general method is the use of a blanket of suitable material over the bath to remove impurities by chemical action.

The term *holding* in melting practice refers to holding the metal after it is melted, either in the melting furnace or in an auxiliary furnace, for refining, for adjustment of pouring temperature, or simply for regulation of the flow of metal to conform to plant operation.

Metal Classification. A grouping of metals with reference to melting service is given in Table I. Group I includes the soft metals and Group II the hard metals. An alloy belongs in the group in this table to which its major component belongs.

Another grouping is the classification of the nonferrous metals as light metals, aluminum and magnesium and alloys of these metals, and heavy metals, mainly copper and its alloys.

Charges. The charge of a melting furnace may be scrap metal only, a mixture of scrap metal and virgin metal, or virgin metal only.

Melting Furnaces. There are two types of induction furnaces for melting metals: (a) the coreless induction furnace,⁽¹⁾ sometimes referred to as the high-frequency induction furnace; and (b) the submerged resistor furnace,⁽²⁾ which operates with a standard power frequency, usually 60 cycles.

TABLE I

MELTING POINTS OF HARD AND SOFT METALS

Metal	Melting Points	
	Deg C	Deg F
Group I: Soft Metals		
Tin	232	450
Bismuth	271	520
Cadmium	321	610
Lead	327	621
Zinc	420	788
Antimony	630	1166
Magnesium	651	1204
Aluminum	659	1218
Group II: Hard Metals		
Silver	961	1761
Copper	1083	1981
Nickel	1452	2646
Cobalt	1480	2696
Iron	1530	2786
Molybdenum	2535	4595
Tungsten	3400	6152

NOTE. The melting temperature ranges of any *alloy* must be obtained from the constitution diagram of the alloy system to which the alloy belongs.

CORELESS INDUCTION FURNACE

The general design of this furnace is shown in **Fig. 1**. The metal is melted by currents induced in the charge. Thus basically this furnace differs from an induction heater that operates at below-melting-point temperatures only in the provision of a refractory chamber, or crucible, for the charge.

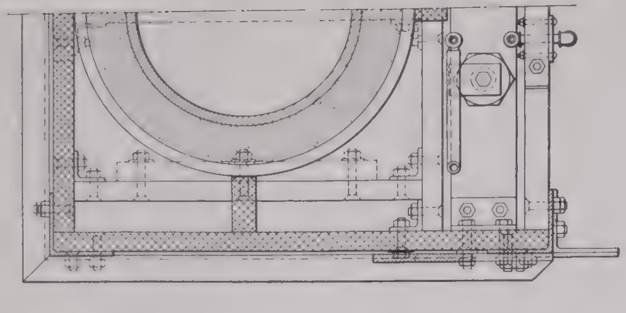
Prior to his retirement in 1946, Mr. Stansel was for years a member of Industrial Engineering Divisions of the Apparatus Department, General Electric Company.—ED.

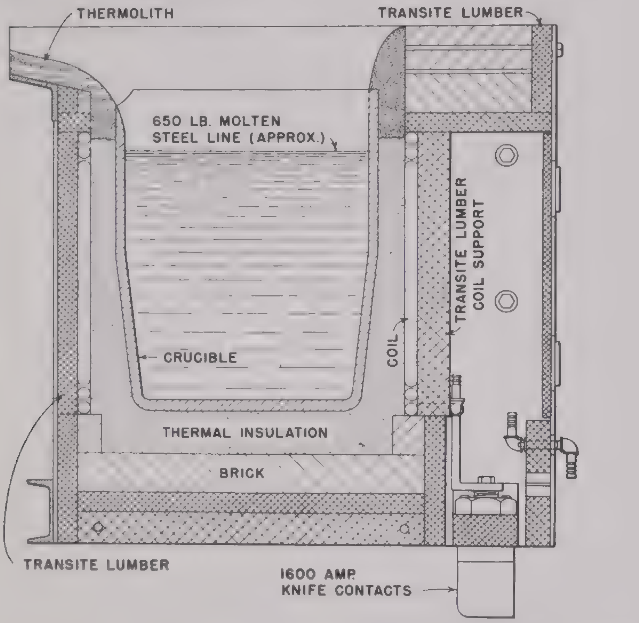
This article will constitute part of the book *Induction Heating* by N. R. Stansel to be published by McGraw-Hill Book Company (New York). It is preprinted here by permission of the author and publisher.—ED.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 35 to 42.—ED.

(1) "The Development of The Coreless Induction Furnace," by G. H. Clamer, *Metals and Alloys*, vol. 6, May, 1935 p. 119.

(2) "The Development of the Submerged Resistor Furnace," by G. H. Clamer, *Metals and Alloys*, vol. 5, Nov., 1934, p. 242.





(*Ajax Electrothermic Corporation*

Fig. 1. Sectional view of a coreless induction furnace

The main parts of the assembly are:

(a). The crucible

(b). The primary coil, or inductor

(c). The frame, including its supports and a mechanism for tilting the furnace for pouring.

Crucibles. Preformed crucibles, as indicated in **Fig. 1**, are used for small furnaces—up to about 500 lb holding capacity.

The crucibles of larger furnaces are made in place by ramming a granular refractory material around a hollow form. This construction is indicated in **Fig. 2**. Acid or basic refractories are used as required.

The inner portion of the wall of a rammed crucible—the lining—becomes sintered with use to a certain depth, one half inch or more. The outer portion of the wall remains in granular form and serves as a support for the lining, as thermal insulation, and as a barrier against the leakage of molten metal if a crack occurs in the lining.

Primary Coils. The single-layer water-cooled primary coil is used in standard practice. The view of a partly assembled furnace in **Fig. 3** shows the primary coil in place.

Frame. A standard construction is a wood frame as shown in **Fig. 3**, with nonmagnetic metal for fastenings. Conventional types of mechanisms for tilting the furnace for pouring are used. General practice is to fit the frame of the furnace with trunnions so placed that the furnace tilts about a horizontal axis which passes through the pouring spout.

Furnace Mountings. The three standard mountings are:

(a). Platform mounting (**Fig. 4**). This mounting provides for maintaining the electric power input to the furnace while pouring.

(b). Floor-level mounting (**Fig. 5**). This mounting permits the use of the furnace as a ladle for pouring.

(c). The lift-coil furnace (**Fig. 6**). This design is used mainly for melting comparatively small nonferrous charges.

Service. The coreless induction furnace is primarily a melting unit and is not adapted to refining service. The particular field of service is the production of high-grade

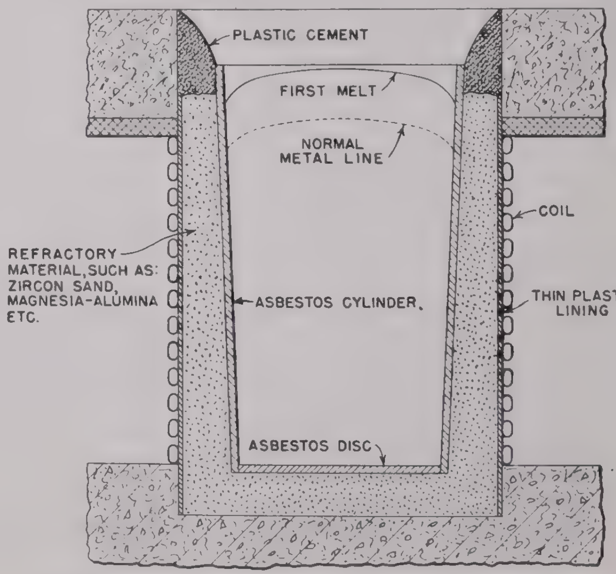
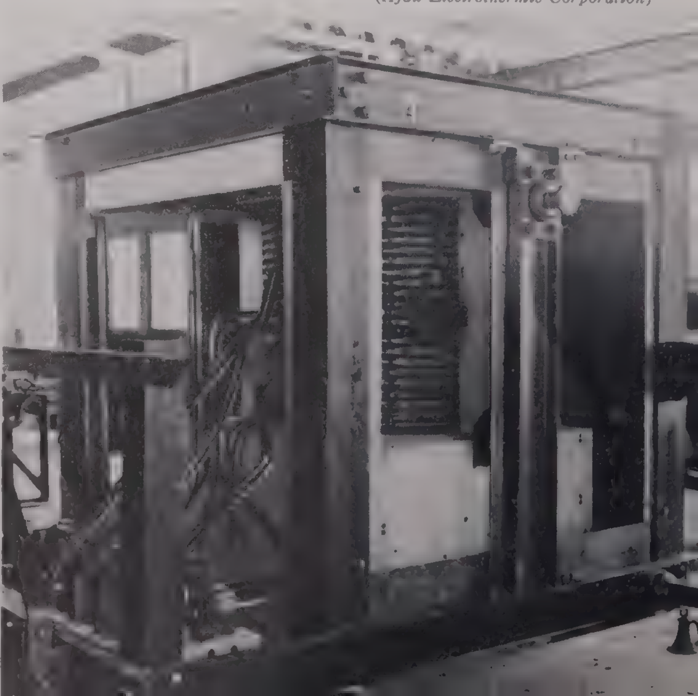


Fig. 2. Diagram showing the method of making a rammed crucible

Fig. 3. A partly assembled coreless induction furnace
(*Ajax Electrothermic Corporation*)



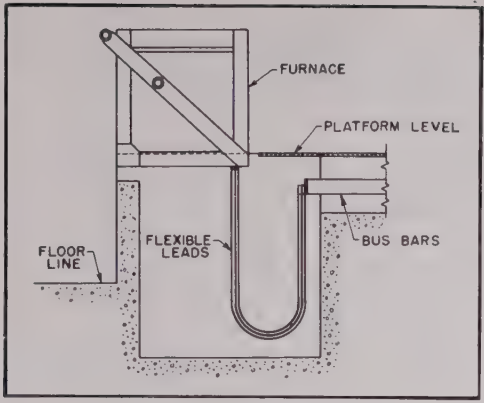


Fig. 4. Platform mounting of coreless induction furnace

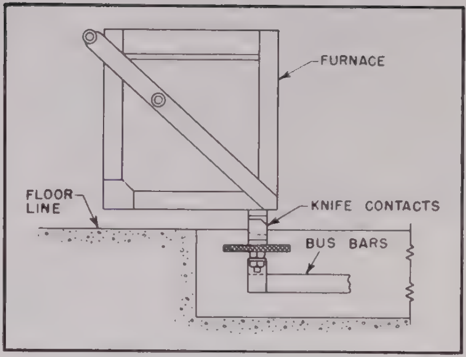


Fig. 5. Floor mounting of coreless induction furnace

alloys such as bronzes, stainless steels, gun steels, magnet steels, tool steels, nickel-chromium alloys, and bearing metals.

Standard Sizes. A partial list of standard furnaces and the average performance data in steel melting service are given in Table II.

TABLE II

STANDARD CORELESS INDUCTION FURNACES

(*Ajax Electrothermic Corporation*)

Size Kw	Size, Pounds of steel	Steel Melting Performance		
		Minutes of melting time	Pounds per hour	Kw-hr per 2000 lb
50	200	110	125	850
100	500	120	300	825
250	1000	80	750	700
350	2000	125	900	725
700	4000	135	1800	700
1250	8000	135	3500	675

Operation

Operating Periods. The operation of a melting furnace is divided into four periods: charging time, melting time, holding time, and pouring time.

There may or may not be an idle period after pouring.

Charging. Inasmuch as the secondary circuit of the furnace is formed in the annular zone of the charge—which initially is composed of pieces of metal—the manner of charging the furnace (sizes of pieces and placement) has much to do with the performance of the furnace circuit during the initial period of the heat cycle. A careful placement of the charge to give a favorable secondary circuit is advisable.

Filling Coefficient. This term denotes the percentage of the internal volume of the crucible which is occupied by cold scrap metal when the crucible is filled to the top plane of the primary coil. Values of this coefficient range from 40 to 90 per cent; the latter value is infrequent. The average value is around 50 per cent.

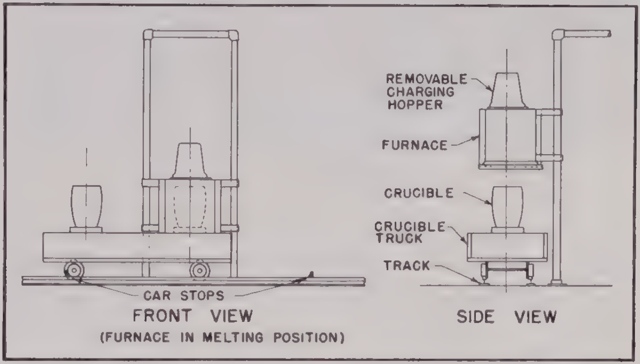


Fig. 6. The lift-coil type of coreless induction furnace

After-charging. The volume of the charge shrinks as it melts. A full charge of molten metal is obtained by adding cold metal after a portion of the initial charge is melted.

Stirring. A unique feature of the coreless induction furnace is the automatic stirring of the molten metal as indicated in **Fig. 7**. This movement is the result of the interaction of the magnetic fields of the primary and secondary circuits. The resulting effect is proportional to the square of the ampere-turns and inversely proportional to the density of the molten metal.

This stirring of the molten metal with the consequent mixing of the components of an alloy is an important factor in the production of high-grade alloys.

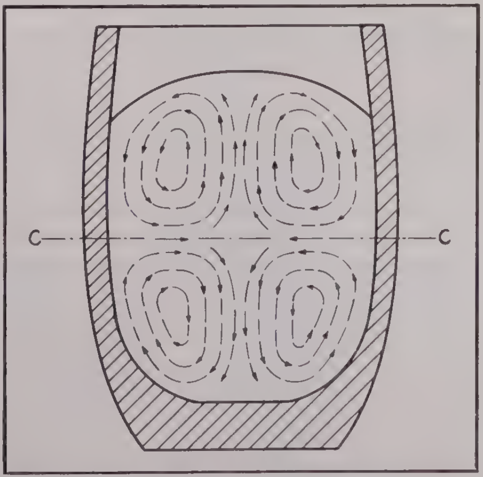


Fig. 7. Diagram of the stirring effect within a mass of molten metal being heated by eddy currents

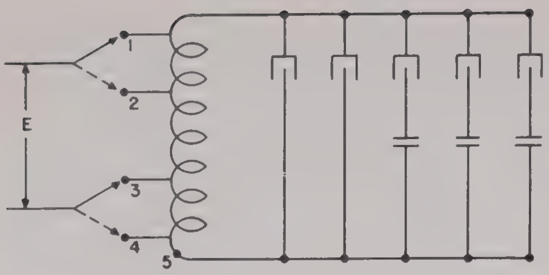


Fig. 8. Circuit diagram of a coreless induction furnace

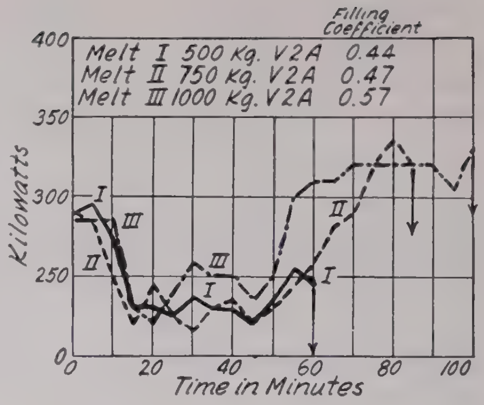


Fig. 10. Power-time records of a coreless induction furnace during the melting of steel charges

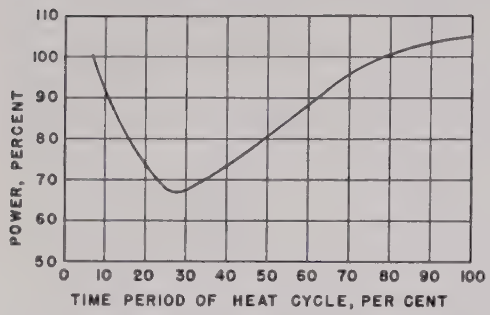


Fig. 9. Power-time characteristic of a coreless induction furnace (constant voltage)

Operation Data. The data of Table III by Badenheuer(3) are typical of medium-size furnaces in steel melting service. The log of a heat cycle of a 1250-kw coreless induction furnace is given in Table IV.

Electrical Features

Circuits. A simplified diagram of the circuits of a coreless induction furnace, including the connections of the capacitors for power-factor improvement, is shown in **Fig. 8**. This diagram indicates the use of the primary coil as an autotransformer with taps in the winding for adjustment of furnace power. These features may or may not be used, according to the operating conditions.

The special electrical features of a furnace circuit are:

(1). A comparatively large air-gap.

(2). Initial formation of the secondary circuit by the pieces of the charge adjacent to the wall of the crucible and by the contacts between these pieces. As the metal melts, the resistance introduced by these contacts disappears, and the height of the charge decreases.

(3). The effect of the filling coefficient, equivalent to an increase of charge resistivity in inverse proportion to the value of that coefficient.

(4). The stirring action in the molten metal.

Frequency. The primary technical factor in the selection of frequency for a melting furnace is the desired degree of the stirring action. Inasmuch as the current required for a given power value decreases with an increase of frequency, and as the stirring action is proportional to the square of the ampere-turns, a too violent stirring action is avoided by so selecting the frequency as to limit the ampere-turns to a permissible value.

No evaluation of the degree of stirring desirable in a given furnace can be given. The effect should be moderate, and there is much leeway. Consequently the selection of frequency can be, and is, considered jointly with the economics of the service.

TABLE III
OPERATION DATA OF CORELESS INDUCTION FURNACES IN STEEL-MELTING SERVICE

Melt Number	Pounds of charge	Filling Coefficient	Minutes of melting time	Pounds per hour	Kw-hr per 2000 lb
I	1100	0.44	60	1100	660
II	1650	0.47	85	1165	607
III	2200	0.51	100	1320	585
IV	1650	0.66	81	1218	587
V	1650	0.58	102	970	742
VI	1650	0.77	97	1020	660

TABLE IIIa (*Supplement to* TABLE III)
ALLOCATION OF LOSSES, KILOWATT-HOURS PER 2000 POUNDS

Melt Number	Cooling Water	Radiation	Electrical Apparatus	Total
I	163.60	17.60	138.90	320.10
II	138.0	22.10	124.90	285.0
III	131.30	9.87	121.83	263.0
IV	117.70	9.20	120.10	247.0
V	172.0	82.0	153.0	407.0
VI	161.80	22.85	135.35	320.0

Fig. 11. A typical installation of coreless induction furnaces
(*Ajax Electrothermic Corporation*)

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(3) "Construction and Operation of Large-size Coreless Induction Furnaces," by F. Badenheuer, (In German) *Stahl und Eisen*, vol. 55, Aug. 1, 1935, p. 821.

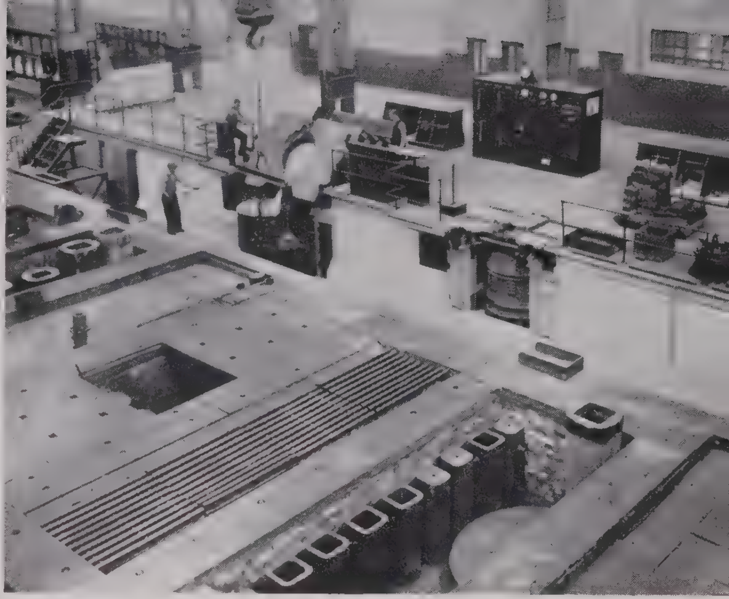
TABLE IV

LOG OF 1250-KW 960-CYCLE MELTING FURNACE, INITIAL CHARGE 4930 LB OF CARBON STEEL SCRAP

Time	Volts	Kilowatts
1:40	800	1050
1:45	860	1150
1:50	700	750
1:55	1000	950
2:0	1060	900
2:05	1200	1000
2:10	1250	1075
2:15	1150	1050
2:20	1200	950
Power off to add 500 lb of scrap to charge		
2:20	1200	1050
2:35	1050	800
2:40	1150	900
2:45	1150	1100
2:50	1150	1000
2:55	1100	950
3:0	1100	925
3:05	1200	1000
3:10	1200	1000
3:15	1200	1000
Power off for 20 minutes		
3:35	One-half power for 15 minutes	
3:50	875	600
3:55	1175	1025

Standard Frequencies. The consideration noted in the preceding paragraph led to the early adoption in this country of 960 cycles as the standard frequency for steel-melting furnaces above 100 kw. As a rule, this frequency is also suitable for melting nonferrous charges, although 480 cycles is favored in some instances.

The corresponding standard frequency for smaller industrial furnaces is 3000 cycles. Various higher frequencies are used for laboratory furnaces.



(Metropolitan-Vickers Electric Co., Ltd.)

Fig. 12. An installation of coreless induction furnaces in England

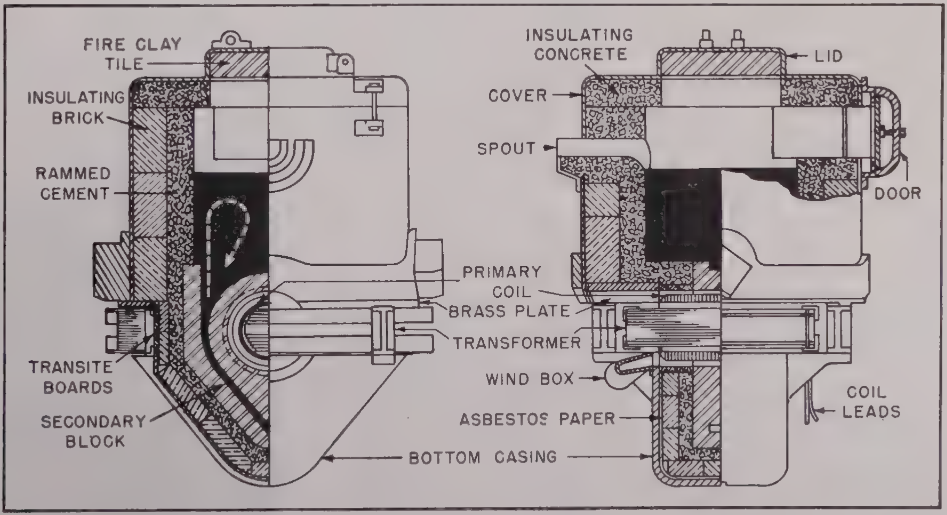
Power-time Relation. A general representation of the power-time relation of a melting furnace which starts with a cold charge is shown in **Fig. 9**.

There are many erratic variations from the general relation shown in **Fig. 9**. Some examples of records of this kind from a steel-melting furnace, given by Badenheuer,(3) are shown in **Fig. 10**. The data which pertain to these graphs are included in Table III. In each case the condition of the charge permitted after-charging after 45 minutes from the start of the heat cycle.

Installations. A typical installation of coreless induction furnaces is shown in **Fig. 11**. The installation in **Fig. 12** is in a steel plant in England. (That installation is described in *Metallurgia*, vol. 3 (1934), pages 167–170.)

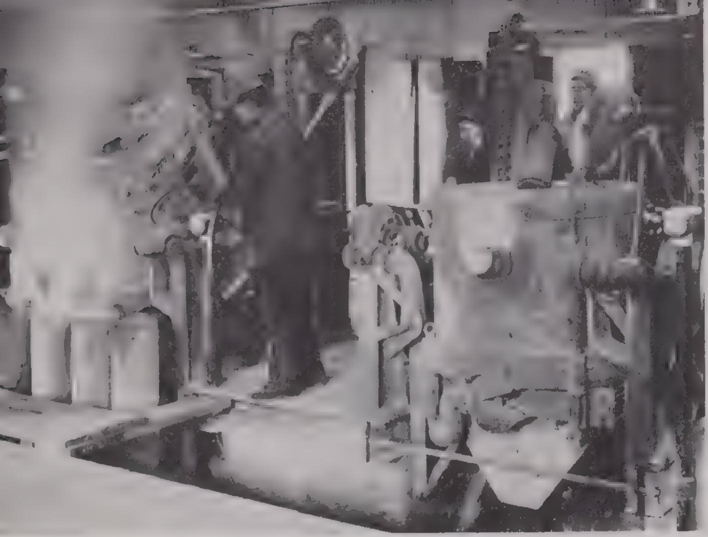
SUBMERGED-RESISTOR FURNACE

The general design of the submerged-resistor furnace is shown in **Fig. 13**. The furnace has two main parts (1) a refractory-lined chamber, or crucible; and (2) a transformer heating unit mounted below the crucible.



(Ajax Electric Furnace Corporation)

Fig. 13. Sectional views of a submerged resistor furnace for melting brass and similar alloys



(*Ajax Electric Furnace Corporation*)

Fig. 14. Installation of submerged resistor furnaces

The heat is developed in the secondary circuit of the heating unit. This circuit is formed by a loop of molten metal in a vertical refractory-lined channel and connected to a bath of molten metal in the crucible above. A laminated iron core with a primary winding completes an otherwise conventional air-cooled transformer for a standard-frequency power circuit, usually of 60 cycles.

The current induced in the secondary circuit forces by electrodynamic action a movement of the molten metal in the channel, as indicated by the arrow in **Fig. 13**. Thus the heat developed in the secondary circuit is transferred to the mass of the metal in the crucible. Metal is melted by feeding cold metal into the bath of molten metal in the crucible.

The starting of the furnace requires a priming charge of molten metal sufficient in quantity to close the loop of the secondary circuit. For day-by-day operation, the furnace is left charged—or partly charged—at the end of the working period, and a reduced voltage is applied to hold the metal in liquid state during the idle period.

The design of the furnace with a V-shaped channel, shown in **Fig. 13**, was developed for melting the heavy nonferrous metals and alloys, such as copper, brass, and bronze. Standard sizes of this furnace for batch melting range up to 300 kw single-phase at standard power frequencies and standard low voltages.

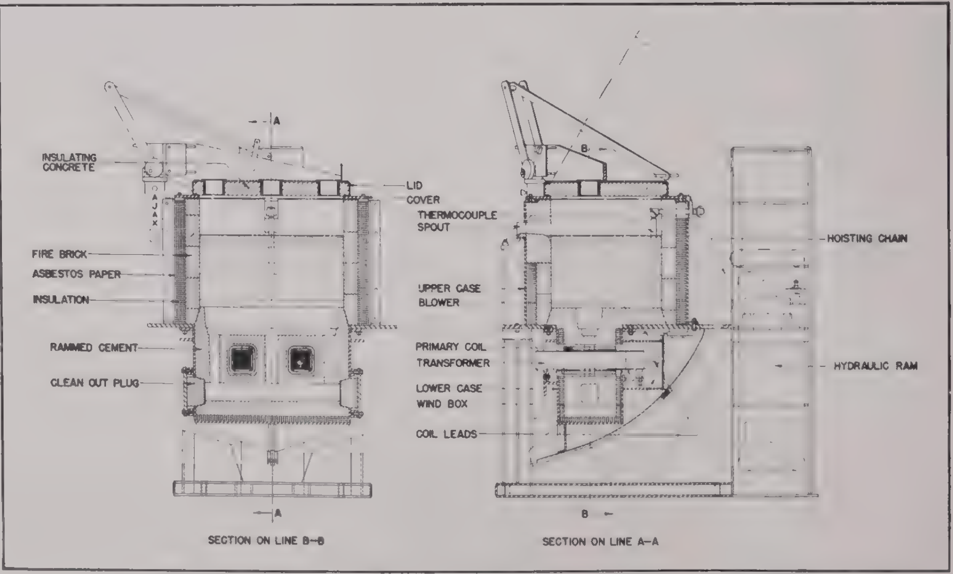
An installation of two of these furnaces—one melting and one being charged—is shown in **Fig. 14**.

Operation Data. The values in Table V are representative for the class of metals and alloys for which the furnace in **Fig. 13** is designed. A feature of its operation is the low metal loss by volatilization, a feature of much importance in melting zinc and alloys which contain that metal.

TABLE V

OPERATION DATA OF SUBMERGED-RESISTOR FURNACES

Charge	Kw-hr per ton	Kw to hold overnight	Per cent of net metal loss
Red brass	252	11	0.40
Yellow brass	195	8	0.30 to 0.60
Alloy: 75 Cu., 2 Sn. 3 Pb., 20 Zn.	200	8	0.50 Zn.
Nickel Silver	275	8	0.50 Zn.
Alloy: 87 Cu., 6 Sn. 5 Zn., 2 Pb.	260	12	0.50 Zn.
Bronze	285	12	0.70 Gross
Copper	310	13	—
Zinc	90	4.5	0.25



(*Ajax Engineering Corporation*)

Fig. 15. Sectional view of a submerged resistor furnace for melting aluminum

Melting Aluminum. The design of a submerged-resistor furnace for melting aluminum(4) and its alloys is shown in **Fig. 15**. A complete furnace is shown in **Fig. 16**.

Fig. 16. A submerged resistor furnace for melting aluminum

(*Ajax Engineering Corporation*)

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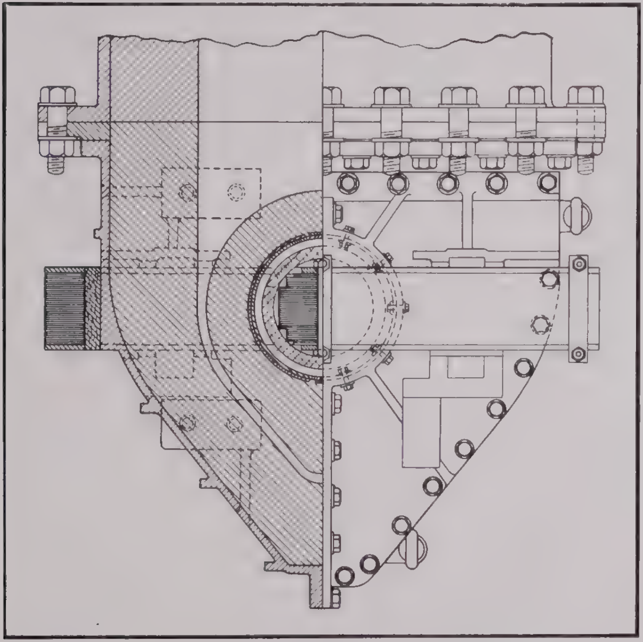
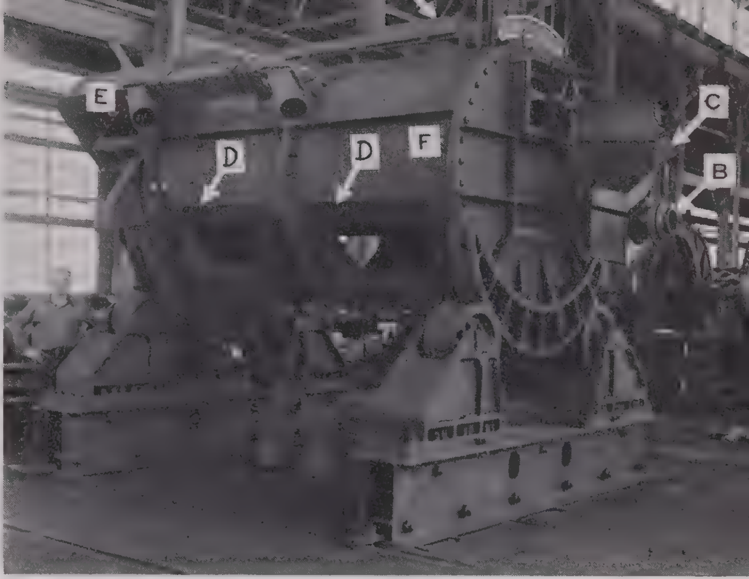
(4) "Induction Furnace for Melting Aluminum," by M. Tama, *Mechanical Engineering*, vol. 66, Nov. 1944, p. 731.

The basic consideration of this design is that the slag particles of the light metals have about the same specific gravity as—or are heavier than—the molten metal; thus these particles tend to sink and clog the channel of the secondary circuit. It will be noted that the vertical channels are connected at the bottom ends by a horizontal channel of larger cross-sectional area. With this construction, the slag particles which accumulate in the channels can be removed from time to time without interferring with the operation of the furnace.

Standard sizes of the furnace for batch melting of aluminum and its alloys range up to 250 kw, single-phase, 60 cycles. A standard 500-kw furnace has two transformer heating-units connected for three-phase service.





(*Scomet Engineering Company*)

Fig. 19. A Type 2-F melting furnace during assembly

A. Charging doors
B. Discharge spout
C. Door for access to throat and to launder between *B* and *C*.
D. Openings in shell for transformer heating units. Two similar openings on opposite side
E. Ducts for cooling air for transformers of heating units
F. Shell of furnace

Continuous Melting Furnaces. The transformer heating-unit of the submerged-resistor-type furnace (either **Fig. 13** for heavy metals or **Fig. 15** for light metals) can be arranged as shown in **Fig. 17** for attachment in any number to large chambers for continuous-melting service. In this service, charging and pouring are done simultaneously.

This use of multiple heating-units is shown in the general design of the continuous-melting furnace shown in **Fig. 18**. A furnace of this type during assembly is shown in **Fig. 19**.

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Fig. 17. A transformer heating unit for bolting to the shell of a continuous melting furnace

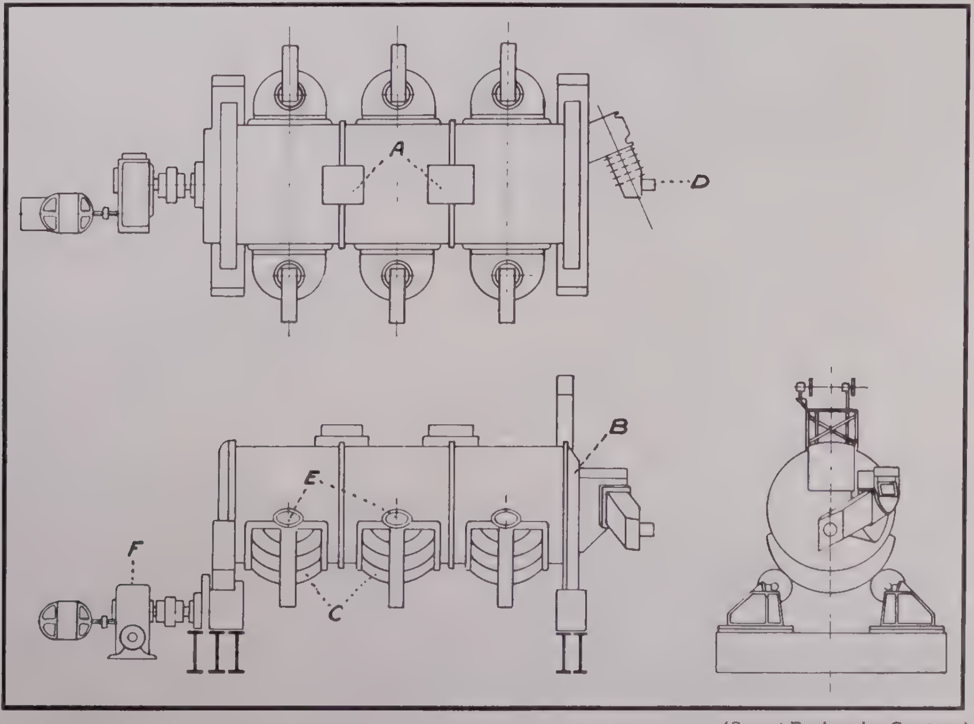

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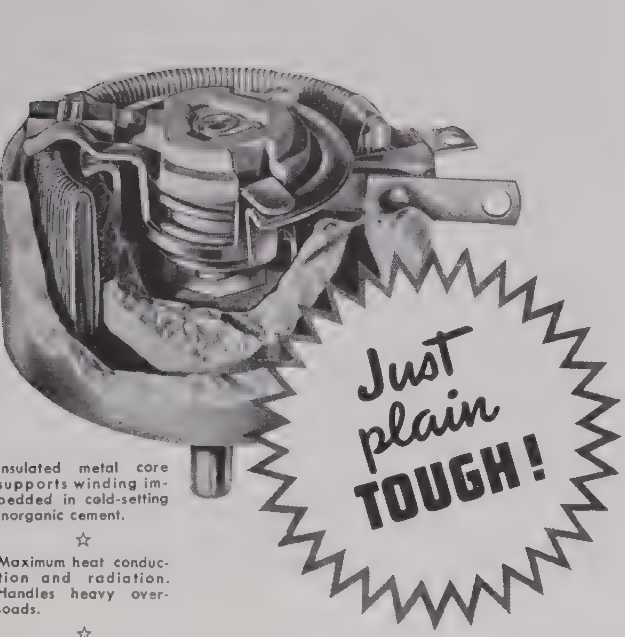
Fig. 18. General design of a Type 3-F continuous melting furnace

A. Charging doors
B. Door for skimming
C. Transformer heating units, each 150 kw
D. Pouring spout
E. Openings for cooling air for transformers
F. Reducing gear

(*Scomet Engineering Company*)



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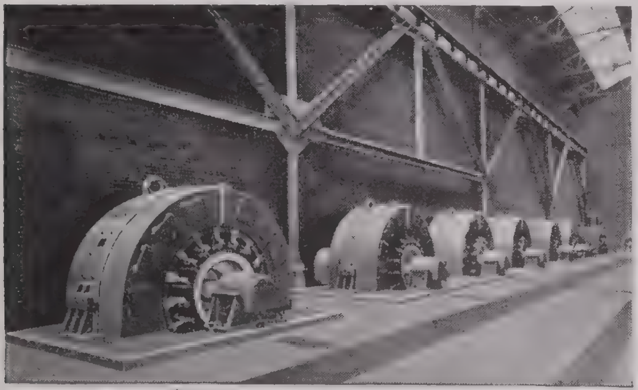
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MELTING METALS

(Continued from preceding page)

General Construction. The cylindrical steel shells of this type of continuous-melting furnace have refractory linings and are mounted on cradles supported by roller-bearing idlers. One of the cradles is geared to a motor-driven tilting mechanism. The arrangement for pouring the melt through a closed launder is seen in **Fig. 19**. The spout B is located on the horizontal axis of the chamber. This feature provides for accurate control of the stream of metal. The operator raises and lowers the outlet from the chamber according to the rate at which cold metal is fed into the chamber.

A thermocouple in the stream of outgoing metal serves through relays for automatic regulation of the temperature of the molten metal by control of the power input.

The openings in the shell of the furnace and the launder are sealed so that a gas atmosphere can be maintained in the chamber and in the launder to prevent the access of oxygen (air) to the molten metal.

Holding or Pouring Furnaces. A common plant arrangement, where two or more continuous-melting-furnaces are used, is for delivery of the metal from the melting furnaces to a holding or pouring furnace and thence to the molds.

The standard sizes of the furnaces shown in **Figs. 18** and **19** are given in Table VI.

TABLE VI

CONTINUOUS MELTING FURNACES

(Scomet Engineering Company)

Type	Service	Nominal Capacity tons of copper, melting service	Kilowatt Rating for melting service
G	Pouring	—	150 (one unit)
1–F	Pouring or Melting	4	300 (two units)
2–F	Pouring or Melting	11	600 (four units)
3–F	Melting	20	900 (six units)

Energy and Rate of Melting. The energy required for melting copper in the furnaces of Table VI is about 250 kw-hr per ton. The corresponding melting rate is 1200 lb per hr per 150-kw heating unit. For example, the melting rate of the Type 3-F furnace is approximately 3.6 tons of copper per hour.

Service. The general service of these furnaces is melting nonferrous metals and alloys. A particular service is melting cathode copper in the production of oxygen-free high-conductivity (OFHC) copper. In this operation, a blanket of carbon in granular form over the bath serves as reducing agent to remove copper oxide from the metal. A protective gas atmosphere, for example, producer gas, is used in the chamber and launder.

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MANUFACTURERS OF ELECTRONIC DEVICES AND SHEET METAL FABRICATION

NOMOGRAPHS FOR COMPUTING EXPONENTIAL RELATIONSHIPS

How they can be used to resolve relationships used in infrared spectroscopy. For an electrical application, condenser discharge through a resistor is determined

By A. H. CANADA
General Engineering & Consulting Laboratory
General Electric Company

A. H. Canada

THE absorption of light or radiant energy bears a fixed relationship to the concentration and the path length of a compound. This relationship is expressed in Beer's law:

> "If two solutions of the same salt be made in the same solvent, one of which is say, twice the concentration of the other, the absorption due to a given thickness of the first solution should be equal to that of twice the thickness of the second."

and by Lambert's law,

> "Each layer of equal thickness absorbs an equal fraction of the light which traverses it."

These relationships are used in infrared spectroscopy to compute pressure or path-length conditions required to obtain certain desired absorption or extinction values. For visible spectroscopy, or color matching, these relationships are used to compute dye concentration.

In the case of dye mixing, the amount of a pigment required to obtain a certain transmission factor may be computed. Such a relationship as this is of particular usefulness in the judicious application of infrared spectroscopy to process control by selection of pressure and path-length conditions for a particular substance to obtain the greatest rate of change in transmission factor for the range of concentrations of the compound under observation.

As a time-saving aid in calculations involving either transmission factor or extinction, two exponential nomographs are presented in **Figs. 1** and **2**.

The absorption or extinction of radiation by a substance is related to its concentration by

$$E = acd \tag{1)*}$$

where

E = extinction or absorption
a = extinction coefficient, a constant for the particular wavelength and compound being considered
c = concentration of the compound
d = path length

Extinction is equal to the logarithm of the reciprocal of the transmission factor.

$$E = \log \frac{I_0}{I} = acd \tag{2}$$

where

I_0 = the radiation incident on the cell
I = the light transmitted by the cell

For the purpose of the nomographs, these relationships are rewritten as exponential forms for liquids and gases:

$$\frac{I}{I_0} = \epsilon^{-ac} \tag{3}$$

$$\frac{I}{I_0} = \epsilon^{-apl} \tag{4}$$

where

ϵ = Napierian base
p = pressure
l = length

In Equation (3), the form used with liquids, path length d is assumed to be unity or fixed for any series of tests and thus does not appear. Equation (4), on the other hand, deals with absorption in gases; therefore, concentration c is replaced by pressure p, assuming a fixed temperature for any series of tests. Path or cell length l is substituted for d in this form. Per cent transmission is 100 times the transmission factor I/I_0.

Application to Color Matching

A nomograph for Equation (3) is given in **Fig. 1**. This consists of: concentration factor, a logarithmic cycle on the abscissa; extinction coefficient, a portion of a logarithmic cycle as the ordinate; and transmission factors in log-logs from 0.8 to 0.1 plotted diagonally, the slope of which is the ratio of the ordinate log-cycle length to the abscissa log-cycle length. The spacing of the transmission scale may be constructed from the log-log scale of a slide-rule.

Example for Fig. 1. A hypothetical example of the use of this nomograph is as follows: In compounding a certain dye, 300 units of pigment are added to a batch of dye. The per cent transmission of a sample of the resulting solution is measured at the wavelength affected by the pigment and found to be 40 per cent. Extinction coefficient is found by reading 3 for 300 units on the abscissa, moving down the nomograph to intersect 40 per cent, and then moving horizontally to

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*This is a combined form of Lambert's and Beer's laws. Lambert's law shows that the extinction E is a linear function of the path length d; Beer's law shows extinction to be a linear function of the concentration c of the compound.

This article is so paged that, without mutilating other articles, it can be conveniently removed for separate filing by tearing out pages 44 to 47.—ED.

read the extinction coefficient 0.307 on the ordinate. This coefficient will remain constant for that pigment and that wavelength. It is desired, however, to obtain 20 per cent transmission. The amount of pigment that needs to be added can be found by moving horizontally across the nomograph (constant extinction coefficient) to 20 per cent transmission and then reading down to 5.25, or 525 units, on the abscissa. Thus, 525 units would have given the desired concentration, requiring 225 additional units of pigment to obtain the desired transmission.

Concentration *c* is purely arbitrary for any compound. It can be in pounds, barrels, hand-fulls, etc. If the scale is calibrated for a particular material at a characteristic wavelength and the extinction coefficient is known for the material and wavelength, the chart may be used to determine the amount of the particular material present from the transmission measured at that wavelength.

Application to Infrared Spectroscopy

The nomograph in **Fig. 2** is based on Equation (4). Instead of expressing concentration as a single factor it is expressed in pressure and cell length for a gas, and particular units are arbitrarily assigned. The left ordinate is extinction coefficient in two log cycles. The abscissa has two log cycles and is the product of pressure and cell length. The right ordinate is pressure in

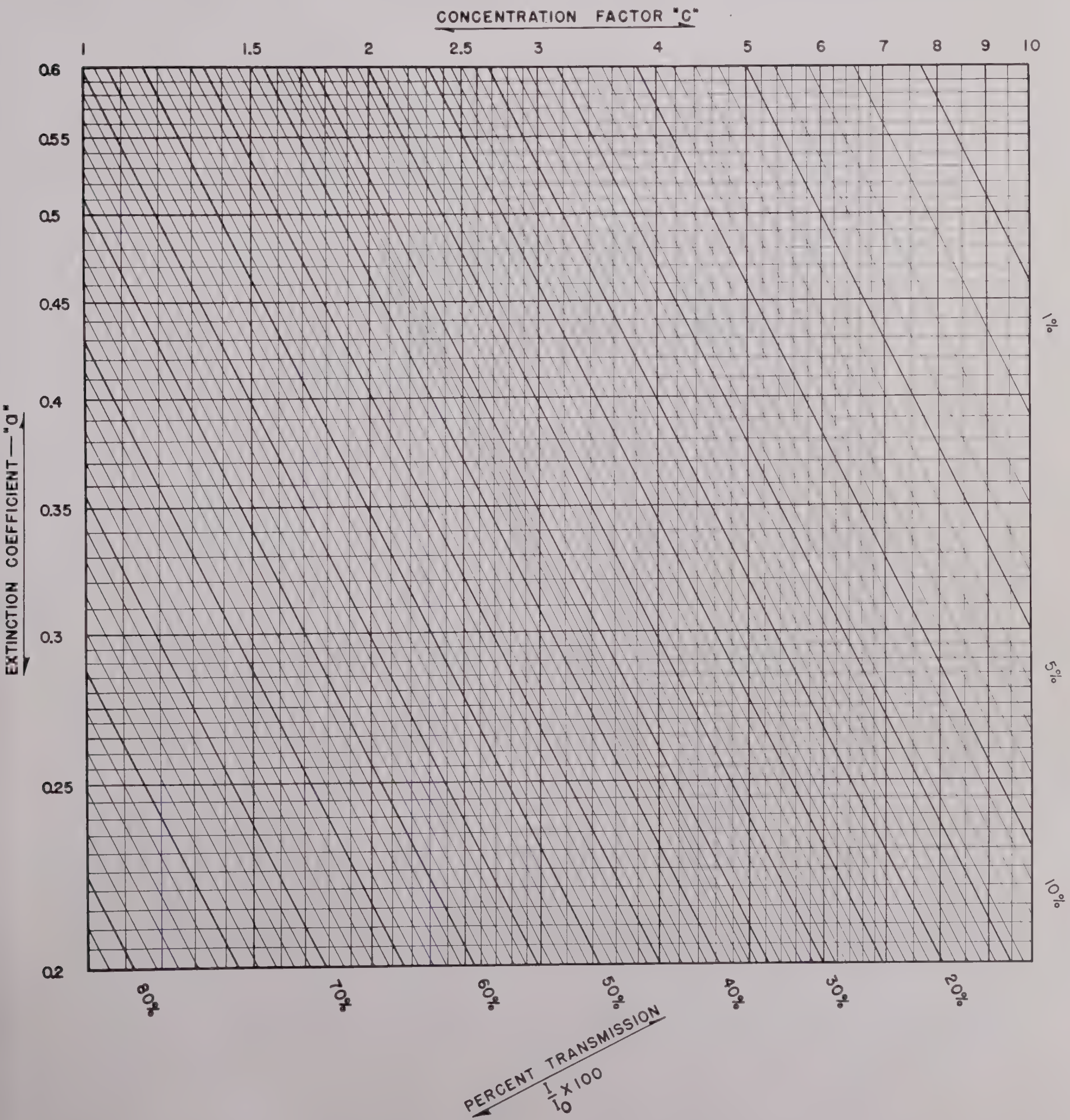


Fig. 1. Nomograph for Beer's law for various concentration factors

centimeters of mercury and is two log cycles. On one diagonal is cell length in centimeters in two log cycles; on the other diagonal are log-logs from 0.98 to 0.01, multiplied by 100 to be per cent transmission.

Example for Fig. 2. A hypothetical example of the use of the chart in **Fig. 2** is as follows: In an infrared absorption spectrum chart a particular wavelength for a particular gas at atmospheric pressure in a 10-cm cell has a transmission of 80 per cent. It is desired to obtain the extinction coefficient, the pressure to reduce transmission to 60 per cent if the cell length is constant, and the cell length for 60 per cent transmission if the pressure is held constant. The example is illustrated in **Fig. 2** with the heavy lines. Atmospheric pressure (76 cm of mercury) on the right ordinate is read first. Extinction coefficient is found by moving horizontally from this point to intersect the cell length 10 cm, then vertically to intersect the given transmission 80 per cent on the log-log scale, and then horizontally to the left ordinate gives the extinction coefficient 0.0003.

Next, moving horizontally (extinction coefficient constant) to the desired 60 per cent transmission on the log-log scale and moving vertically to the 76 cm of mercury line gives a 23-cm cell length, for pressure held constant; continuing up to intersect the 10-cm cell length on the diagonal gives 173 cm of mercury pressure when cell length is held constant.

For continuous process measurement at a critical absorption band of a compound, the extinction coefficient can be determined. The nomograph in **Fig. 2** can then be used to convert per cent transmission to the partial pressure of the compound being measured.

This type of nomograph presented in **Figs. 1** and **2** is of interest wherever exponentials are encountered.

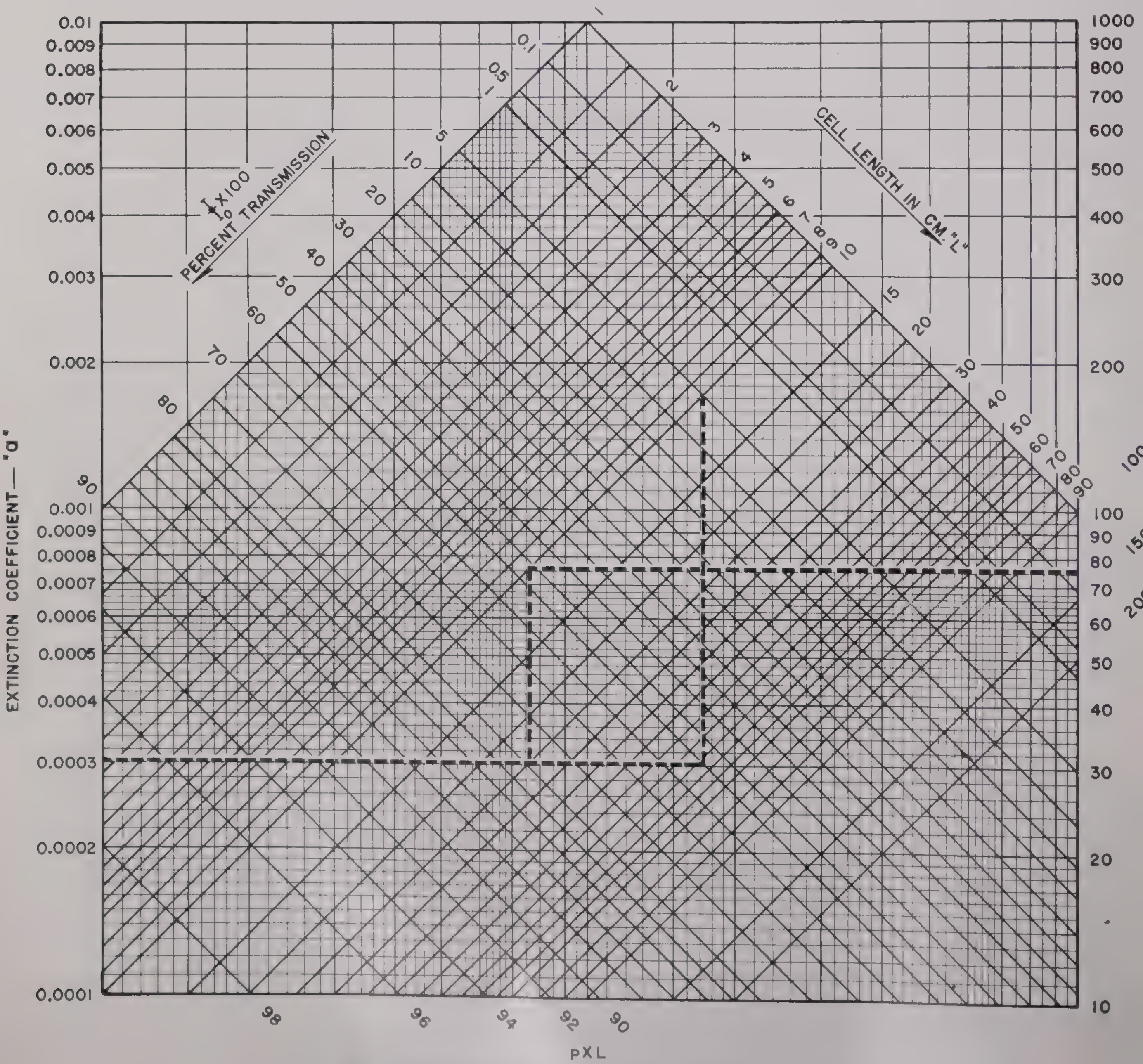


Fig. 2. Nomograph for Beer's law for radiation absorption of gas

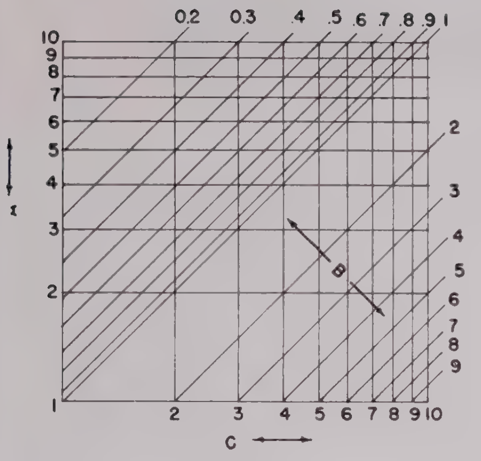


Fig. 3. Nomograph which obtains the straight multiplication of $ab = c$

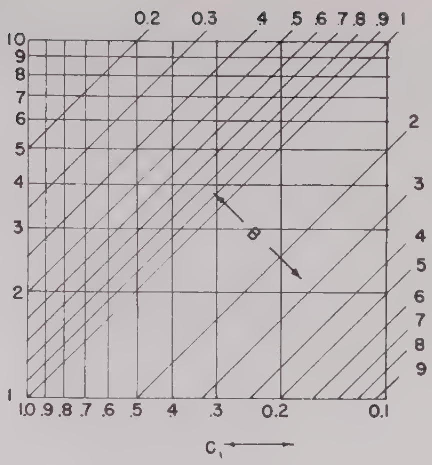


Fig. 5. Inversion of the abscissa to obtain the relation $ab = 1/c$

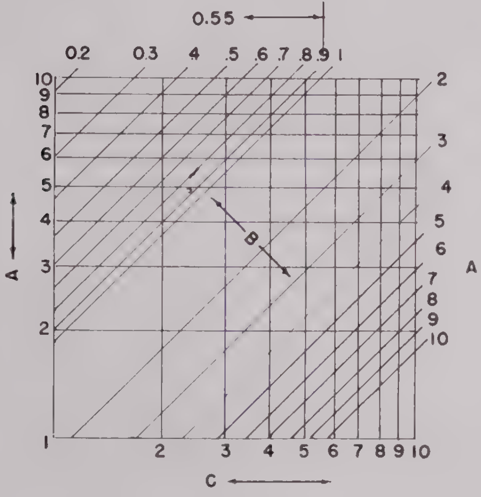


Fig. 4. Modification of Fig. 3 to include a constant in the equation. Here the relation is $0.55\ ab = c$

Relationships to Provide Other Nomographs

Figs. 3, **4**, and **5** show relationships of logarithmic scales used to obtain various forms of exponents and indicate other forms of exponential nomographs.

A straight multiplication relationship is obtained as in **Fig. 3** when the abscissa, ordinate, and diagonal read left to right, bottom to top, and left to right respectively as shown. This of course may be modified by slipping one of the log scales (**Fig. 4**) to include a constant, thus making the relationship $ab \times 0.55 = c$.

When one log scale, the abscissa in **Fig. 5**, is inverted, the relation becomes

$$ab = 1/c, \text{ or } c = 1/ab \tag{5}$$

Electrical Applications

Equation (5) is directly applicable to the voltage ratio equation for a condenser of capacitance C discharging through a resistor R

$$\frac{E}{E_0} = \epsilon^{\;t/RC} \tag{6}$$

where

E/E_0 is the ratio of voltage at time t. E_0 is the initial voltage.

A sample form of nomograph for this relationship is given in **Fig. 6**. As in **Fig. 5**, the reciprocal of the product of the ordinate value and the diagonal value appears on the abscissa. The log-log cycle is a diagonal facing the opposite direction from that in **Figs. 1** and **2**, since the abscissa log scale is reversed.

Example for Fig. 6. As an example, for a capacitor of 10 μf discharging into 5000 ohms, the voltage ratio after 80 millisec and the time constant, or the time at which it reaches $1/\epsilon$ of the initial condition, are to be determined. By reading the intersection of 5000 ohms and 10 μf and moving vertically to intersect the 80 millisec horizontal, the voltage ratio 0.2 can be read on the diagonal log-log scale. The time constant is 50 millisec, as determined by the intersection at the $1/\epsilon$ diagonal.

These and a number of other time-saving nomographs may be devised by engineers for routine calculations involved in various exponential or natural logarithmic relationships, and the possibilities are limited only by the engineer's ingenuity in adapting the nomograph to the specific application at hand.

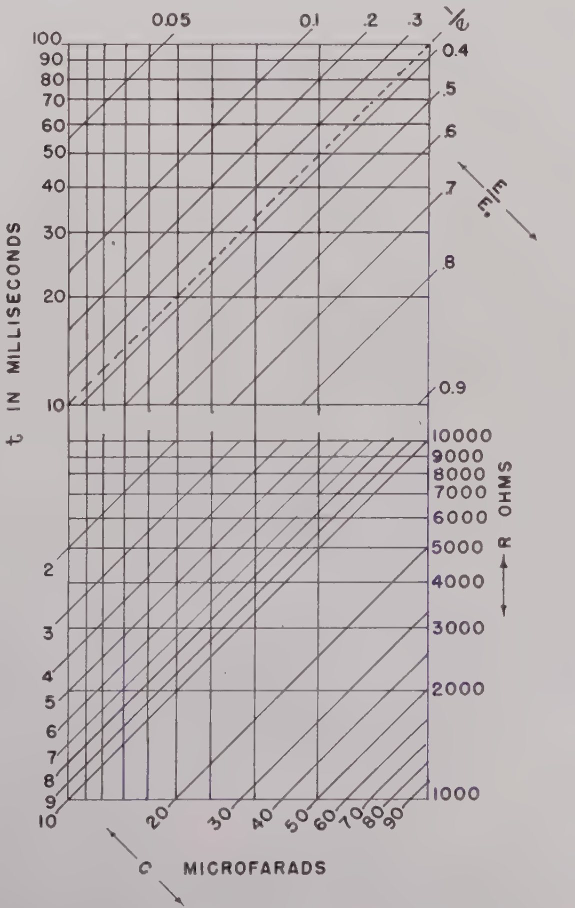
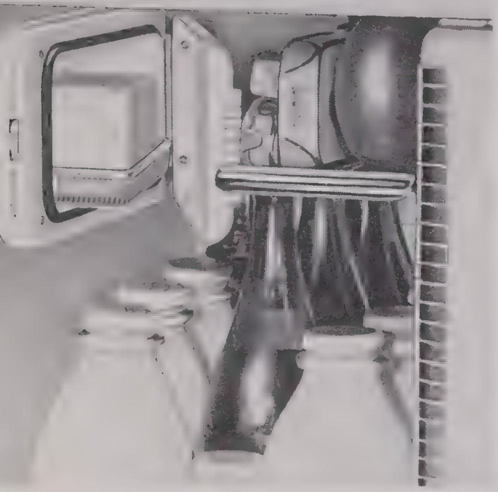


Fig. 6. Nomograph for the discharge of a condenser through a resistor

HIGH LIGHTS AND SIDE LIGHTS

Butter Conditioner



A butter conditioner, a device for keeping butter at smooth spreading temperature, is a feature of a new de luxe refrigerator recently announced. Built into the left wall, the conditioner holds a pound of butter at the temperature indicated on the dial

Electronic Heating

Electronics utilized in heat-treating permits selective heating of front- and rear-wheel motorcycle hub assemblies. Localized heat makes it possible to silver-braze the brake drum and spoke flange to the hub without heating the entire work.

In the equipment used in the heat-treating department of the Harley-Davidson Motor Co., Milwaukee (Wis.), the hub assembly is placed over a copper coil which induces radio-frequency current into the work. Molecules jostling under the influence of current changing 520,000 times per second create speedy heat. One complete brazing operation is performed every 40 seconds by the electronic heater, which delivers 15 kw of power.

Other fixtures can be connected to this heat generator in many possible applications. For example, motorcycle clutch hub pins are casehardened in the center cylindrical device. The pins are inserted in a one-turn copper coil which induces the radio-frequency current into the work unit. The rapidly alternating current exercises the phenomenon of "skin effect"; that is, the high-frequency current hugs the surface of the metal, thereby heating the pin to a shallow depth. Immediate quenching casehardens the metal to the desired depth of 0.04 in.

The speedy electronic process eliminates the need for lengthy carburization and shortens production time. Only 4¼ seconds, for example, are required to completely caseharden the pin.

Testing Air for Beryllium

A technique for testing the air of machine shops to detect the rare element beryllium in quantities as minute as six trillionths of a pound has recently been put into service.

A small pump draws in the air to be tested through a tube, the mount of which is placed where the face of a worker is normally located when any given machine is cutting a beryllium alloy. The apparatus inhales 0.2 cu ft of air each minute: this approximates half the breathing rate of most adults.

The air is passed through a fine filter capable of snaring the tiny beryllium fragments. These particles, if present in quantities greater than 0.000000000006 of a pound, are detected by burning the filter in a furnace, then placing the ash in an electric arc before a spectrograph, a light-analyzing instrument.

Beryllium is used in many alloys for strength, lightness, and corrosion resistance.

Radio for Norway's Fishermen

Official inauguration of the first 100-kw international shortwave transmitter to be placed in operation in Scandinavia took place January 3 when King Haakon VII and government officials spoke on a program beginning at 10 p.m. Norwegian time, from Fredrikstad, Norway. The program was broadcast on 31.22 meters, or 9610 kilocycles.

The giant transmitter was purchased by the Broadcasting Division of the Norwegian Telegraph Administration to provide home news and music for sailors of Norway's scattered fishing fleet.

At night the transmitter will be used to broadcast special programs to the fishing fleet and to other Norwegians outside Norway from 12:30 to 1:30 a.m. During the day the ordinary Norwegian broadcasting programs will be carried.

The most modern and high-powered shortwave transmitter in Scandinavia, the station has been reported heard in the United States recently when it was on the air for testing purposes.

Giant Accelerator

A new accelerating device, the largest of its kind in the world, is now being designed and built for the Office of Naval Research. It will subject pilots and instruments to high accelerations similar to those experienced in modern military aircraft in sharp turns or pulling out of dives.

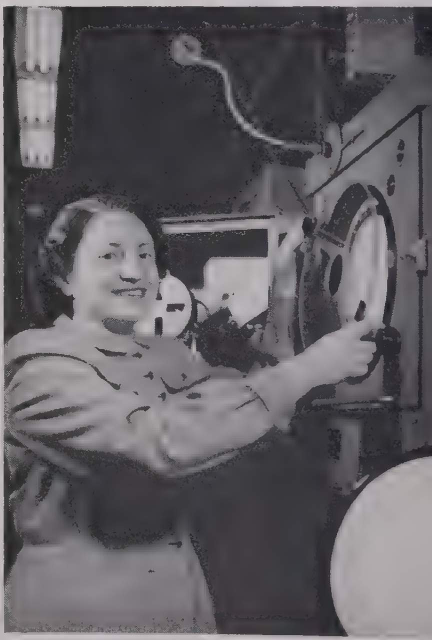
The equipment will be used to determine the forces a man can withstand under such conditions, and for developing protective devices and means for extending the limits determined.

The accelerator will consist of a car or gondola, mounted at one end of a 50-ft horizontal arm, which will be directly attached to the shaft of a 4000-hp electric motor. An automatic electronic control system will cause the motor to follow closely any predetermined speed programs.

The device will be capable of speeding up and slowing down at the rate of 10 times that of gravity. A peak acceleration of 40 times that of gravity will be obtainable, thus permitting the testing of equipment for guided missiles and rocket projectiles.

In emergencies, stopping will be accomplished by first slowing down the machine through dynamic braking, then bringing it to a halt by air brakes similar to those used on buses and trains.

Testing Picture-tube Color



The color in a television picture tube is being tested in the above photograph. One of the jobs of the electronics engineer at work here is to make sure that tubes are all a "daylight white," a color described as the light that is seen in looking at the sun when it is behind a slight haze of clouds. Three methods are used to obtain this color: spectrophotometric curves, relative transmission through a series of filters, and comparison with a sample of standard color

Electrostatic Accelerator to Aid Nuclear Study

An electrostatic accelerator is being constructed for the Brookhaven National Laboratory at Upton (N.Y.). The accelerator, one of several electronuclear machines planned for this atomic research center, will be installed during 1948. Brookhaven Laboratory is being built and administered as a regional center for the Northeast by Associated Universities, Inc., under the auspices of the U. S. Atomic Energy Commission.

It is reported that the machine, rated at 3,500,000 electron volts, first will be used for "source focussing" studies to determine, in part, the designs of other larger machines and associated equipment for the laboratory.

Ultimately, however, it will serve as a source of high-energy particles to be directed in a beam at target elements for a variety of fundamental studies of the atomic nucleus. For example, in some experiments the particles will be employed to study the processes of "chipping" or "splitting" atomic nuclei into such fragments as the radioactive isotopes now widely applied in research.

The electrostatic accelerator, also known as a Van de Graaff generator, has an output energy considerably lower than such machines as the synchrotron, betatron, cyclotron, synchrocyclotron, and linear accelerator. However, it has the advantage of supplying high-speed atomic particles at a uniform energy.

In this new accelerator, electrostatic charges are "sprayed" on two moving belts and carried to an isolated electrode in a steel tank. Particles are shot in a straight line from this sphere through a tube to a target of the element to be studied.

The belts in the new machine will travel at a rate of 4500 fpm. They will be 20 in. wide and will move over pulleys 9 ft apart. Because they will be operated in a nitrogen atmosphere having a pressure of 200 psi, two 10-hp motors will be required to drive each belt.

The entire machine will be housed in a 30,000-lb steel tank, 18 ft long and 8 ft in diameter. The tank's face plate, which will support much of the weight of the atom smasher, will be 9 in. thick. A special building, with 2-ft-thick concrete walls, will be built to house the machine.

New Luxury Liner Sails

The new luxury liner, the S.S. *President Cleveland*, largest passenger vessel built in America since 1939, left San Francisco December 27 on her maiden voyage to the Orient. The *President Cleveland* will visit Honolulu, Manila, Hong Kong, Shanghai, and Yokohama and will return to San Francisco via Honolulu.

With a passenger capacity of 550 and a crew numbering well over 300, the 610-ft, 23,500-ton-displacement ship has a cruising range of 17,600 nautical miles and a cruising speed of 19 knots. She is driven by twin-screw turbine-electric drives.

Each propeller is powered by a synchronous motor having a maximum continuous rating of 10,000 hp. Power for the motors is supplied by two steam turbine-electric propulsion units located in separate engine rooms, each having a main generating plant. While both generators must be used for normal speed, either of them can be used to propel the ship. Auxiliary power for lighting, refrigeration, pumping, and the galleys is supplied by four 500-kw steam turbine generating sets. The vessel's total generating capacity is approximately 23,000 hp.

A feature of the *President Cleveland* is the electronic navigator, an adaptation of wartime radar, which aids in plotting a course, day or night. A radar picture of obstacles in the ship's path is picked up by rotating antennae. The obstacles are reflected as bright spots on the face of a 7-in. cathode tube. Fixed electronic marker circles on the screen of the viewing console give an indication of the distance of objects from the ship. These markers are calibrated in two-, six-, and 30-mile ranges and are controlled by a three-position switch.

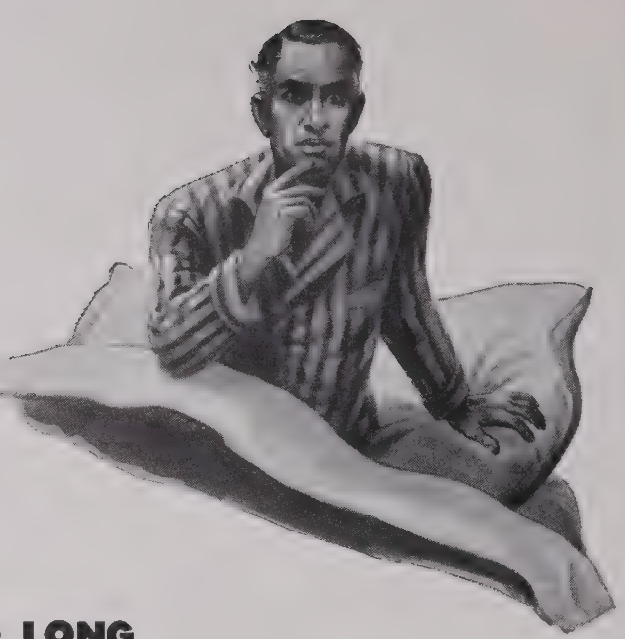
Also aboard is a portable x-ray unit which will be used for emergency radiography in the x-ray room and in surgery.

A complete photographic darkroom is another feature of the ship's equipment.

An interior view of the wheelhouse of the new S.S. *President Cleveland* and (top) the main control board in the engine room.

The new liner *President Cleveland*, at the start of her trial run, passes Golden Gate Bridge, San Francisco (Calif.)

the Corporation President



WHO ALMOST SLEPT TOO LONG

T. M. Stanton* was having a nightmare. For months he'd been preoccupied with the production problems of Empire Gadgets, Inc. So preoccupied, he'd even half-admitted to himself that he was devoting far less thought to national problems than a leading citizen should. But the urgency of his immediate interests kept shoving these concerns into his subconscious mind. Now they were torturing his sleep.

"T. M., old boy," one spectre was saying, "how would you like a nice black depression to come along and swallow up your whole company?" And a green-eyed ogre leered, "While you're neglecting your free-enterprise system, we're moving in with *another* system!"

Stanton's body lurched. "No!" he thundered. Awakened, he scratched his head, murmuring, "Gad, what a dream! H-m-m—wonder what sort of contribution I ought to be making . . ."

Here's Something, Mr. President, You Ought to Do Right Away!

Check up on the status of the Payroll Savings Plan in your company. By making U. S. Savings Bonds easily available to your employees "on the installment plan," it benefits not only the employees but your business and the nation as well! Here's how:

(1) The Payroll Savings Plan builds financial security for each participant. The Bonds pay $4 at maturity for every $3 invested.

(2) The experience of 19,000 companies operating the Payroll Savings Plan shows that it makes employees more contented in their jobs—cuts down absenteeism—even reduces accidents!

(3) The Plan helps to spread the national debt and thus helps secure your business future. How this works is clearly and briefly described in the free brochure shown below.

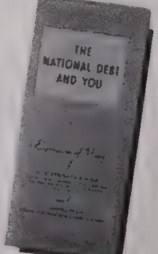
Why Executive Backing Is Vital

Employees still want the benefits of the Payroll Savings Plan. In fact, they *need* the P. S. P., because banks don't sell Bonds on a partial-payment plan—which is the way most workers prefer to buy them. But war-time emotional appeals are gone. Human nature being what it is, the success of the Plan in your company is liable to dwindle unless a responsible executive *keeps promoting it.*

So—today—*check up* on the status of the Payroll Savings Plan in your company. *Act* on your responsibility to see that it is vigorously maintained.

The State Director will gladly help.

Be sure to read this! *"The National Debt and You," a 12-page brochure, brings you the views of W. Randolph Burgess, Vice Chairman of the Board of The National City Bank of New York —and of Clarence Francis, Chairman of the Board, General Foods Corporation. Request your copy from the Treasury Department's State Director, Savings Bonds Division.*



**This one is fictitious—but it might be any corporation president.*

The Treasury Department acknowledges with appreciation the publication of this message by

GENERAL ELECTRIC REVIEW

This is an official U. S. Treasury advertisement prepared under the auspices of the Treasury Department and The Advertising Council.

BACKGROUND TO ACHIEVEMENT

Sydney★

—capital of New South Wales—and one of the largest cities in the Southern Hemisphere, is highly industrialised and its factories produce a wide variety of commercial and industrial goods. Other claims to fame are the beauties of its Harbour, Port Jackson; its Harbour Bridge with a single span of 1,650 feet, carrying a roadway, two footways, two railway tracks and two tram tracks; and its graving dock, newly completed, which takes the world's greatest ships.

★BTH supplied turbo-generators for the Electric Light and Power Corporation of Sydney; switchgear for the Bunnerong Power Station; rectifiers for railway electrification, etc. Mazda Lamps are used extensively for all forms of lighting.

BTH RUGBY

I.A.109

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED, RUGBY, ENGLAND

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Transformers

A new series of commercial-grade components includes: audio components; input transformers; and modulation, power, and filament transformers. Of sturdy mechanical construction, these units are designed with low temperature rise and good insulation factors to assure dependability in continuous service. Coil structures are vacuum impregnated, and cases are poured with special sealing compounds to assure stability under adverse climatic conditions.–*United Transformer Corp., 150 Varick St., New York 13, N. Y.*

Electrode Holder

New water-cooled light-duty holder for resistance-welding electrodes, designed for making hard-to-reach spot welds. The holder incorporates a button-type replaceable electrode held in place by an easily removed screw. Water cooling is efficiently brought as near the electrode as possible to insure maximum electrode life under the most severe usage. Almost four inches of offset adjustment is available by merely setting the amount of offset desired and setting two bolts in the T connection head.—*P. R. Mallory Co., Inc., Indianapolis 6, Indiana.*

Injection Cylinder

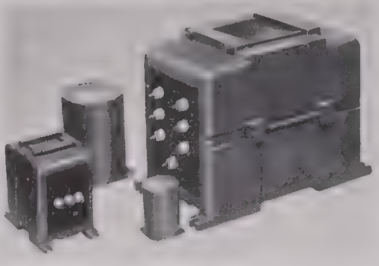
An injection cylinder with independent temperature control in its spreader and a completely annular material passage. This cylinder, designed for all thermoplastics—including vinylite and nylon—makes possible the molding of large pieces on intricate molds. Advantages include: increased plasticizing rate for any given inventory of material; more effective pressure transfer from plunger tip to nozzle; and ease by which the material is passed over the tip of the spreader.—*Lester-Phoenix, Inc., Cleveland, Ohio.*

High-precision Pivots

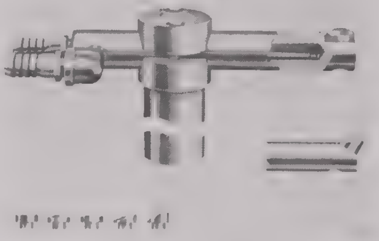
Pivots manufactured in volume, by high-precision method in which a special steel of high-alloy content is used. This steel is hardened in controlled heat-treating furnaces having a high degree of accuracy. The point of the pivot is then precision engineered on a true radius and the tip ground to the geometric equivalent of a segment of a sphere. The finished product is highly polished to a mirror-like finish by a special process.—*Springfield Instrument Bearing Co., 909 MacArthur Blvd., Springfield, Ill.*

Metallizing Gun

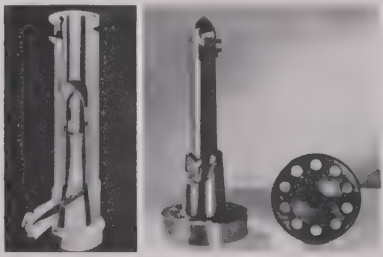
The new light-duty low-air L gun requires air at a rate of only 10 cu ft per min for metallizing. This gun has a new turbine construction requiring relatively little power, making a large compressor unnecessary. The nozzle construction assures lower cost per pound of metal sprayed because of the low consumption of acetylene and oxygen. The turbine control requires only one adjustment for the entire range of metallizing wires. Weighing 4 lb 2 oz, this gun can be hand- or machine-operated to spray all kinds of metals.—*Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City 1, New York.*



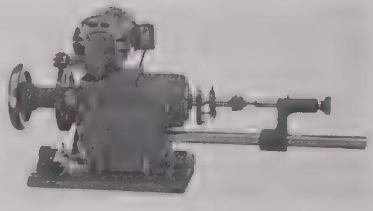
Transformers



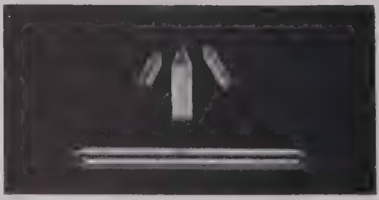
Electrode Holder



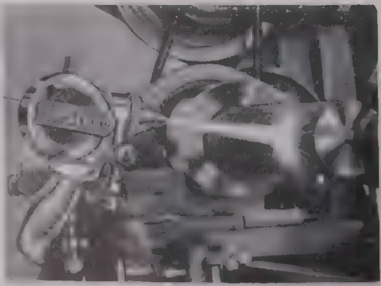
Injection Cylinder



Tool-grinding Fixture



High-precision Pivots



Metallizing Gun

Mercury Switch

A silent-operating mercury switch with a 10-amp rating at 125 volts replaces the 5-amp switch formerly used. Doubling the interrupting capacity in the new switch opens wide fields for its use; the 5-amp model could not be used to control a light or a bank of lights comprising more than 600 watts. The mercury in this switch is contained in a metal enclosure which consists of mercury-to-mercury contacts enclosed in two special metal-alloy disks that are glass-sealed on a ceramic barrier. Hydrogen gas in the "button" prevents oxidation of the mercury and cools and quenches the arc when the circuit is broken.—*Appliance & Merchandise Dept., General Electric Co., Bridgeport 2, Conn.*

Extruded Tubing

Extruded vinyl tubing known as Natvar No. 400 has been approved by Underwriters' Laboratories for continuous operating temperatures of 105 C. In applications where coated-fabric sleeving and tubing have previously been required, savings in material, labor, and waste are being made by manufacturers of electrical and electronics equipment. The tubing is particularly suitable for operating conditions that require both oil resistance and high heat resistance. It can be readily distinguished from other tubings by its temperature marking of four ridges equally spaced around the circumference and running the length of the tubing.—*The National Varnished Products Corp., Woodbridge, N. J.*

Tool-grinding Fixture

A new radial-relief fixture is now being produced commercially for use by tool shops. Radial-relieved cutting tools, used on screw machines or vertical-type equipment, are capable of reducing set-up time, machine-running time, and maintenance cost. This fixture removes a minimum of stock behind the cutting edge, allowing clearance that is adequate, but no more than necessary. The fixture is easily installed on any universal tool-grinding machine by simply removing the grinder headstock. No special cams are needed to regulate spiral or radial relief; all teeth cut in a true circle; and the work centerline remains parallel to the axis of the grinder.—*Glenbard Tool Mfrs., Inc., 216 N. Clinton St., Chicago, Ill.*

Rubberized Material

Fel-Pro 131 is the name of a new synthetic-rubber material of high tensile strength and low compression set. Able to withstand extensive immersion in various fuels, oils and solvents, the material can also be subjected to a wide range of temperatures. The stock can be furnished in the specified hardness required, and it can be cut, molded, or extruded to suit individual applications. Samples will be sent to manufacturers who report their specific requirements covering size or shape, application, etc.—*Felt Products Manufacturing Co., 1504 Carroll Ave., Chicago 7, Ill.*

New Heavy-duty Laboratory Centrifuge

A new heavy-duty hand-power centrifuge designed to swing two to four 100-cc tubes with minimum effort. The features include ball bearings throughout, and a 24-to-1 gear ratio that permits reduced crank speed. The outer diameter of swing is 16 in., and there is a stationary guard bowl to reduce air resistance and protect the operator from whirling parts. The entire unit can be stowed in the bowl when not in use.

This centrifuge can be used for many tests in plants which are processing or using petroleum products, foods, paints, pharmaceuticals, and for general laboratory uses involving precipitation, sedimentation, or extractions.—*The Gerin Corp., P.O. Drawer 653, Red Bank, N. J.*

Pressure Transducer

A new pressure transducer, Type 4713, for operation in the pressure range of ±20 in. of water is dome-shaped, small, and light in weight. This transducer, utilizing the slack-diaphragm principle of measurement, is particularly suited to galvanometer recorders, strain gages, telemetering links, and other applications where small differential pressures need to be measured. One end of a spring-linkage movement is fastened to the dome; the other end is fastened to a bellows. Half of the spring is wound counterclockwise; the other half clockwise. A microtorque potentiometer wiper is fastened at the center of the linkage. As the bellows responds to changes in pressure, movement is transmitted to the bellows-end of the linkage. Since the spring is wound in two directions, a small movement at one end induces a large rotation of the wiper on the coil of the microtorque. This results in large voltage variations, or large outputs, for extremely small changes in pressure.—*G. M. Giannini & Co., Inc., 285 West Colorado St., Pasadena 1, Calif.*

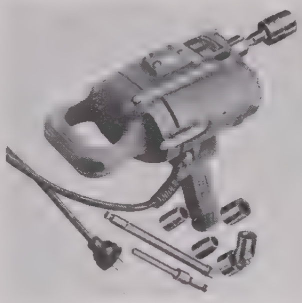
Electrometer Tube

A new "split-anode" electrometer tube, Type GL-5674, which reliably measures currents as low as a millionth of a billionth of an ampere, is expected to prove valuable in nuclear, medical, and industrial research. It is a "two-tubes-in-one" device in which the electrodes (control grid and plate) are cut in two and so connected as to function as a pair. Measurement is then the differential reponse between the two halves of the tube. Since sporadic effects influence both parts alike, the difference between the two responses is independent of incidental fluctuations. The electrometer tube may be used to amplify the current for actuating an indicating or recording device.—*General Electric Co., Tube Division, Electronics Department, Schenectady 5, N. Y.*

Speed Changer

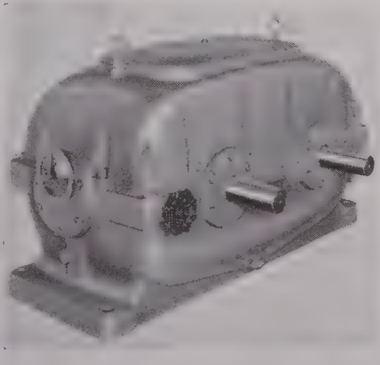
To the present line of P.I.V. variable-gear speed changers a new unit, size H-6, has been added. It is rated 20 hp for speed-variation ratios of 5:1 and 6:1 and 25 hp for speed-change ratios of 2:1, 3:1, and 4:1. This unit is made only in the plain (Type No. 1) basic horizontal assembly with split housing. The housing consists of a top and bottom half, instead of the central housing and side-plate construction used on the smaller gear sizes.—*Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.*

Heavy-duty Centrifuge


Nut Setter

Pressure Transducer

Adjustor


Speed Changer

Nut Setter

The lightweight, high-speed impact nut setter known as Speed-o-matic is electrically operated and produces no torque. Because the unit does not twist in the operator's hands when the nut becomes tightened, this maximum ease of operation with minimum fatigue to operator is accomplished. It operates at high speed, driving nut or bolt 1750 rpm at free speed. At point of resistance, the impact unit automatically delivers 3000 impact blows per minute. The unit is instantly reversible for removing bolts or nuts.

Made of Silman steel forgings for maximum endurance and equipped with precision ball-and-roller bearings, the impact unit is the heart of the tool. It can be removed in 45 sec or less if servicing is needed. —*Illinois Gage & Manufacturing Corp., 4639 W. Washington Blvd., Chicago 44, Ill.*

Impregnating Varnish

A new, clear, quick-baking-type high-heat-resisting varnish No. 8015 has been designed specifically for impregnating and finishing of assembled units and wire-wound elements. Use of this varnish cuts by more than half the baking time ordinarily required for curing purposes, giving completely protected windings in less time and at lower cost. Additional advantages include: internal drying; flexibility, penetration, and long life; strong bonding power; high resistance to acids, oils, and alkalies; and adhesion to copper, steel, and aluminum.

The varnish should be of interest to manufacturers of armatures, field coils, stators, solenoids, transformers and other wire-wound elements used in the electrical industry.—*Industrial Finishes Division, Central Paint & Varnish Works, Inc., New York.*

Adjustor

Levelmatic is a new device for eliminating the wobble in furniture. This device incorporates General Electric Company's bouncing putty in a simple cylinder-and-piston arrangement that automatically adjusts table-leg lengths to uneven floors or rugs. Bouncing putty duplicates the action of a fluid in a hydraulic mechanism, since it acts as a very viscous liquid. Levelmatics accommodate floor variations up to $\frac{3}{16}$ in. and will last an indefinite length of time. They are built to withstand considerable weight, including pianos, since they form a metal-to-metal contact when fully compressed by a severe load.—*Blake Industries, Detroit, Mich.*

Strain Relief

A new addition to a group of strain reliefs is furnished complete with protective spring. The new spring-type relief is for such applications as vacuum cleaners, irons, waxing machines, etc., because it protects the cord from excessive right-angle bending where it enters the appliance chassis. The spring fits into a special groove molded into the nylon relief, and then the unit is assembled by placing the relief over the wire, compressing it with pliers, and slipping it into the chassis. This device increases appliance life by absorbing cord pull, push, and torque and by eliminating strain on terminal connections. Because of nylon's resistance to heat, the device is also useful on melting pots, sanding machines, portable drills, etc.—*Heyman Manufacturing Co., 1200 Michigan Ave., Kenilworth, N. J.*

TRADE LITERATURE

Specialty Capacitors—Information is given on design and development of solid and liquid dielectrics and on quality control of capacitors. Some of the capacitors described are: d-c energy-storage and discharge; high-frequency fixed paper-dielectric; high-frequency blocking and by-pass; and vacuum capacitors. Twenty-eight pages. GEA-640B—*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Twist Drills—Impregnated diamond drills and core bits are described and illustrated in a two-page folder, with added two-page folder giving directions for use. Some of the uses mentioned are drilling holes in glass, ceramics, and cemented carbide. Total of four pages. Bulletin DD-326 and copy entitled "Directions for use of Core Drill and Coolant Feed."—*Fish-Schurman Corp., 230 East 45th St., New York 17, N. Y.*

Nylon Rod and Strip—Notes on physical properties, moisture-absorption data, recommended uses, and photographs comprise this pamphlet about nylon rod and strip. Two pages. Entitled "Polyco Nylon Rod and Strip."—*The Polymer Corp., Reading, Pa.*

Drilling Machine—Several photographs illustrate new drilling machine. Features of construction are listed, and its ability to do general purpose work in tool rooms and plants is pointed out. Four pages. Catalog 67.—*Sibley Machine and Foundry Corp., South Bend, Ind.*

Adjustable Transformers—New models of continuously adjustable autotransformer are described and illustrated with line drawings and lettered photographs. A chart is included to aid in selecting the proper autotransformer. Eight pages. Form 424-H-254712.—*General Radio Company, Cambridge 39, Mass.*

Insulation Tester—Hand-operated insulation tester is described, with operating characteristics, applications, and specifications included. Photographs illustrate internal construction and assembly with line drawings indicating electrical connections. Principle of operation is explained. Twelve pages. Bulletin 21–45.—*James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.*

Steam Turbines—Single-stage and multistage turbines for mechanical drives such as compressor, pump, blower, line shaft, and paper machine are described and illustrated, with cross-section diagrams of complete units part-numbered for component identification. Twenty-four pages. GEA-48-45.—*Apparatus Dept., General Electric Company, Schenectady, N. Y.*

Electronic Equipment—A condensed catalog of transmitting tubes and vacuum capacitors with tables, a replacement interchangeability chart, and text material indicating where respective types are used. A brief section gives points on tube ratings and conservation. Twelve pages. Catalog No. 1-GPW-7.—*United Electronics Company, 42 Spring Street, Newark 2, N. J.*

Stiffness Testers—Instrument specifications for testing from 0.005 in.-lb to 50 in.-lb, for three instruments, the 50-in.-lb tester, 6-in.-lb tester, and the 1-in.-lb tester. Stress-strain curves are presented in a section entitled "Production and Research Testing." Another section outlines stiffness-testing procedure. Sixteen pages. Bulletin 35.—*Tinius Olsen Testing Machine Co., 500 N. 12th Street, Philadelphia 23, Pa.*

Electronic Instruments—Combinations of the instruments described in this booklet, recording, integrating, and controlling instruments, are adaptable to the measurement of temperature, pressure or vacuum, fluid flow, liquid level, speed or position, smoke density, and per cent oxygen and combustibles. Photographs and circuit diagrams supplement descriptive text. Twelve pages. Bulletin 231.—*Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio.*

Welding—The purpose of this service bulletin is to give information to the users of the electric-welding process that will permit them to perform their work with increased efficiency. The bulletin tells where to look for trouble and how to correct it. Mailed without charge to plant managers, electricians, master mechanics, safety engineers, welding engineers, and supervisors. Two pages. Form No. CC-47.—*Tweco Products Co., Wichita 1, Kansas.*

The large number of steps in a Ward Leonard Rheostat enables the operator to set motor speeds accurately, quickly, and smoothly. Resistance elements are protected from corrosion and mechanical injury by Vitrohm insulation. The contact arm travels on solid rectangular contacts, assuring long life. Fifty years of service is not uncommon. Write for complete information. Ward Leonard Electric Co., 62 South Street, Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada. Resistors • Rheostats • Relays • Control Devices.

WARD LEONARD ELECTRIC CO.
Result-Engineered Controls

ELECTRITE

A high grade fibre board for electrical insulation. A material of quality possessing high tensile and dielectric strength. Used by many of the leading manufacturers of electrical equipment.

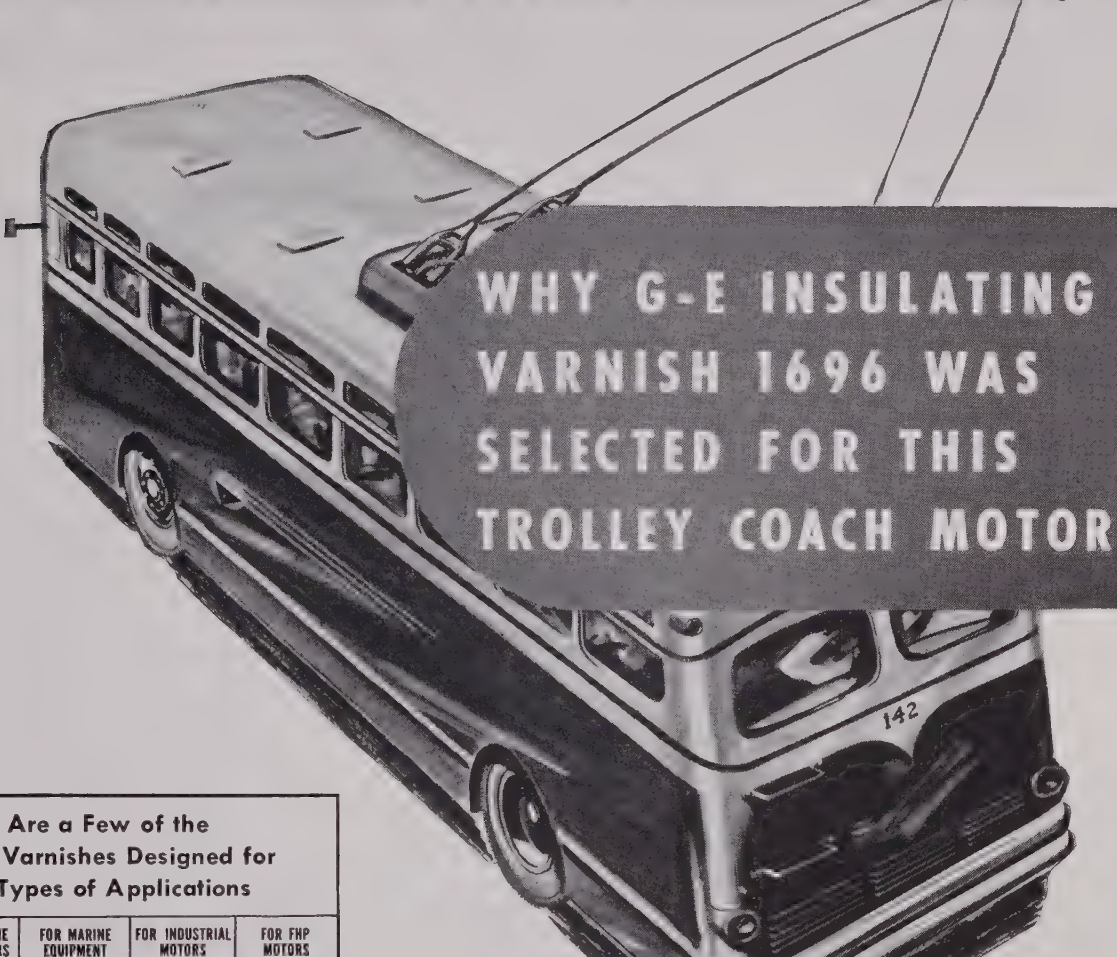
DENSITE

An extremely hard board of superior quality which can replace the more expensive types of insulating materials.

Pulp Products Department

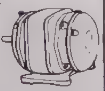
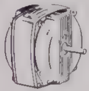
WEST VIRGINIA PULP & PAPER COMPANY
230 Park Avenue, New York, N.Y. 35 E. Wacker Drive, Chicago, Ill.

WHICH G-E INSULATING VARNISH FOR YOUR JOB?



WHY G-E INSULATING VARNISH 1696 WAS SELECTED FOR THIS TROLLEY COACH MOTOR

Here Are a Few of the Many G-E Varnishes Designed for Specific Types of Applications

	FOR MACHINE TOOL MOTORS G-E 1679	FOR MARINE EQUIPMENT G-E 9435	FOR INDUSTRIAL MOTORS  G-E 1678	FOR FHP MOTORS  G-E 9535
BOND	GOOD	EXCELLENT	EXCELLENT	GOOD
DIELECTRIC STRENGTH	EXCELLENT	GOOD	EXCELLENT	EXCELLENT
RESISTANCE TO MOISTURE	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
RESISTANCE TO ALKALI	GOOD	EXCELLENT	EXCELLENT	GOOD
RESISTANCE TO ACIDS	GOOD	EXCELLENT	EXCELLENT	EXCELLENT
RESISTANCE TO SALT WATER	GOOD	EXCELLENT	EXCELLENT	EXCELLENT
PENETRATION	GOOD	GOOD	GOOD	EXCELLENT
TOUGHNESS	EXCELLENT	EXCELLENT	EXCELLENT	EXCELLENT
HIGH TEMPERATURE AGING	GOOD	EXCELLENT	GOOD	GOOD
FLEXIBILITY	GOOD	EXCELLENT	FAIR	GOOD

Order . . .

● Heat and moisture are the worst enemies of insulation in a trolley coach motor. But, General Electric Insulating Varnish 1696 is specially designed to protect motors of this type from the effects of these deteriorating forces.

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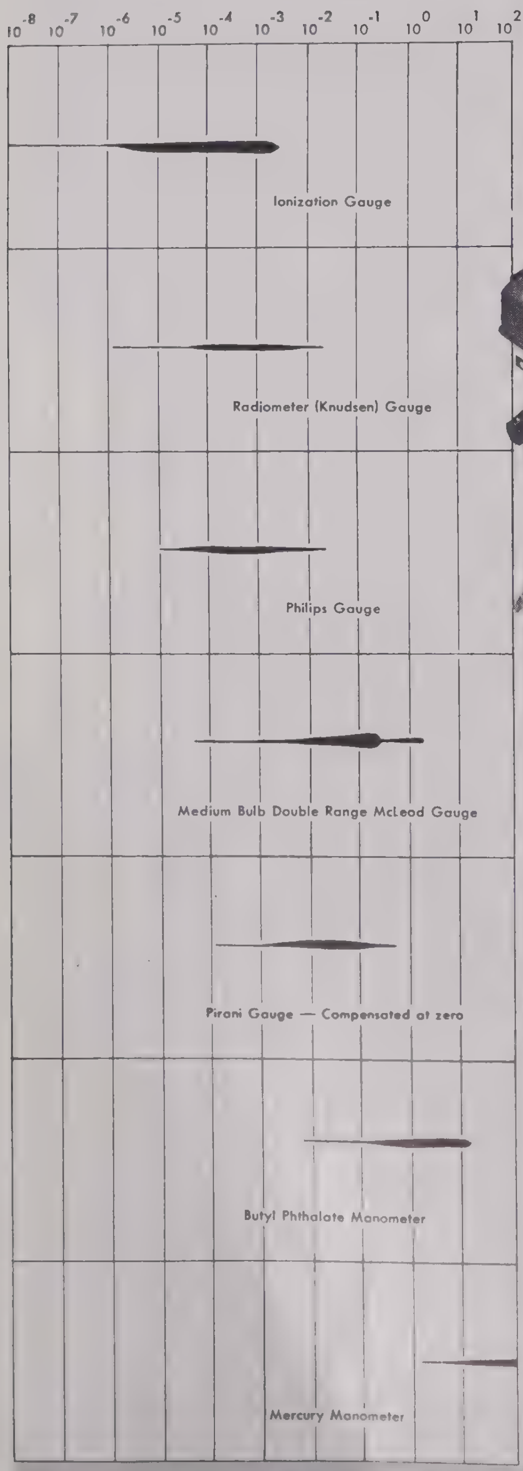

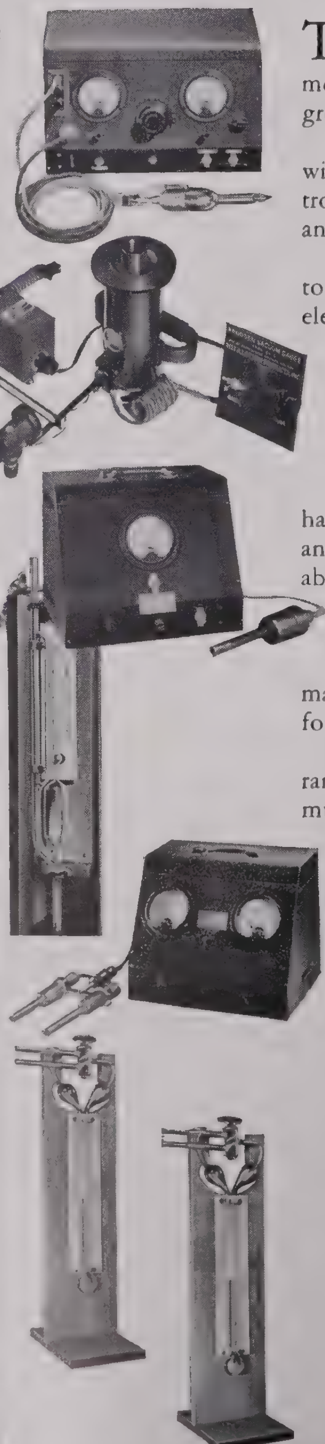

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

Magnetic Control of Industrial Motors.

G. W. Heumann—883 pp. 1947. John Wiley & Sons, Inc., New York. $7.50.

This book has been written to assist the application engineer and user of motor-control equipment in understanding the operation of the devices and circuits involved in a variety of industrial motor controllers. The subject is introduced by a review of motor fundamentals, with particular emphasis on motor speed-torque relationships and the means available for modifying them. Considerable space is devoted to descriptions of a variety of magnetic contactors, relays, and control accessories. The material on control circuits is preceded by a discussion of the basic circuits for push buttons, motor acceleration, reversing, and braking. These individual circuits are presented in several forms, and then used in complete motor-control systems.

The treatment throughout the book is largely qualitative and is well organized. It should serve admirably as an introduction to the motor-control field. The special-purpose controllers dealt with are primarily for use with intermittent-duty motors—for crane, hoist, and similar steel-mill applications. One chapter, devoted to "closed loop" regulating systems, is illustrated by a number of amplidyne control circuits; but the discussion of regulator stability and anti-hunting circuits is hardly adequate for a thorough understanding of these systems.

RICHARD W. JONES

Tables of Spherical Bessel Functions, Volume II.

Prepared by the Mathematical Tables Project, National Bureau of Standards—332 pp. 1947. Columbia University Press, New York. $7.50.

Volume I of this book, reviewed in the G. E. REVIEW of May, 1947, gave values of the functions $\sqrt{\pi/2x}\, J_\nu(x)$ for $\nu = \pm 1/2, \pm 3/2, \ldots, \pm 27/2$ and $x=0$ to 25. The present volume extends the order of the functions to $\nu = \pm 61/2$. In addition, it tabulates the functions $\Lambda_\nu(x) = \Gamma(\nu+1)\, J_\nu(x)/(x/2)^\nu$ for all half-integral orders and some integral orders from $x=0$ to $x=25$. The zeros of $J_\nu(x)$ and $J_\nu'(x)$ ($\nu = \pm 1/2$ to $\pm 39/2$), and certain interpolation formulas, are also given.

G. HORVAY

Alternating-current Machinery.

J. G. Tarboux—652 pp. $6.00. International Textbook Co., Scranton, Pa. 1947.

This attractive 650-page text for senior students of electric machinery devotes about one third of its space to transformers and circuit theory, one third to induction machines, and one third to synchronous machines. The inclusion of a chapter on electronic converters, and emphasis throughout the book on circuit theory, mark this as a distinctly modern book.

One of the marks of good teaching is a "radial" point of view, whereby the relations of each topic to others outside the field of the course are brought out by analogies. In this way, the knowledge acquired is tied into that gained from other sources, and the student gains a broader understanding than he possibly could if restricted to a narrow course. Professor Tarboux has followed this principle by bringing in many analogies, such as the analogies between the circuit theories of machines and those of communication networks, and that between the operation of a multicylinder engine and a polyphase induction motor. The book, therefore, brings together material that will be widely useful to students of communication as well as of power engineering.

P. L. ALGER

The Chemistry and Technology of Waxes.

Albin H. Warth—519 pp. $10.00. Reinhold Publishing Corp., New York. 1947.

There has long been a need for a comprehensive treatment of this subject. The present volume is on the whole a laudable effort to fill that need. The author attempts a survey of the chemistry of natural and synthetic waxes and their definable components from the points of view of the organic chemist, the biochemist, the technologist, and the historian. Although he has succeeded in many respects, it is doubtful that the specialists in any of these fields will be entirely satisfied with the treatment.

He has omitted few, if any, significant descriptive details or physical data relative to the naturally occurring waxes—whether of vegetable, mineral, animal, or fossil—domestic or foreign—common or exotic origin. Synthetic waxes have been considered less exhaustively, and their treatment loses something in coherence by the somewhat arbitrary classifications employed. Recent technical literature in this rapidly growing field, both American and German (government surveys), is on the whole well summarized.

Although the general treatment tends somewhat toward pedanticism, as for example in the inclusion of many rather obvious or tendentious definitions, it is on the whole quite readable. There are more than the usual number of typographical errors.

M. M. SPRUNG

Control Charts—An Introduction to Statistical Quality Control.

Edward S. Smith—161 pp. $3.00. McGraw-Hill Book Co., Inc., New York. 1947.

Quality control is now an accepted and widely used inspection technique. This book has been prepared with the aim of teaching the basic principles to everyone concerned with production. While not exactly a popularization, it does an excellent job of simplification. In a space of just 143 pages, Professor Smith outlines the subject in a truly painless fashion. In fact, he doesn't mention "sigmas" or "standard deviations" until page 132. The type is large, the style is readable; yet it may not satisfy one who prefers to see detailed derivations of all formulas. However, it should appeal to those who are not familiar with mathematical statistics; to those who would like to gain a working knowledge, a speaking acquaintance, with the subject in a minimum length of time.

A. A. MERRILL

Industrial Health Engineering.

Allen D. Brandt—395 pp. $6.00. John Wiley & Sons, Inc., New York. 1947.

The book provides a comprehensive discussion and evaluation of industrial atmos-

(Continued on page 58)

New Books • • •

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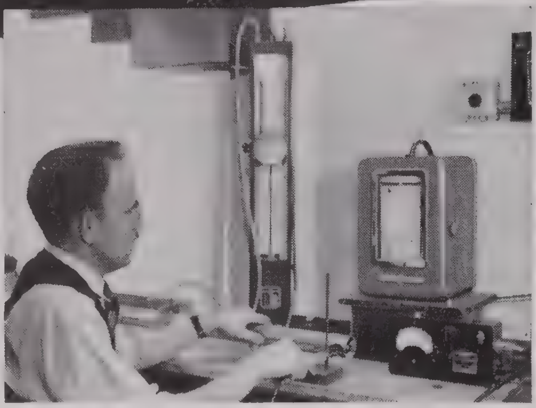

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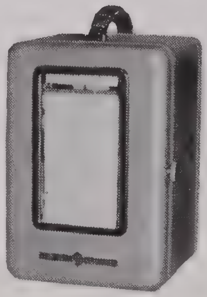

The extreme sensitivity and high-speed response of the photoelectric recorder make it ideally suited to this application, as well as for thermocouple response tests and resistance thermometry. It gives a complete recorded history of these operations.

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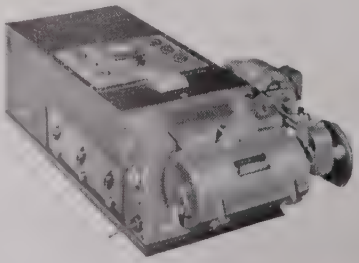

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pheric contaminants that are known to constitute a hazard to the health and life of the worker. Text material is supplemented by numerous line drawings of exhaust equipment and ventilating systems, tables, charts, and graphs. Chapters on "Control Measures for Common Industrial Operations" and "Exhaust Systems—Specific Design Data" should be of considerable value to the plant engineer, the safety engineer, and the industrial hygienist. It is apparent that Doctor Brandt, after years of experience in the field of industrial hygiene, has realized the need for eliminating hit-or-miss methods in the design, installation, and operation of ventilating and exhaust systems for controlling health hazards; and he has attempted to do something about it.

Industrial lighting, the hazards of radiant energy, and the control of industrial noises are also treated. A chapter on "Respirators and Protective Clothing" answers many questions for the safety engineer and industrial toxicologist regarding the use, selection, and maintenance of respiratory devices, as well as the significance of Bureau of Mines approvals.

C. R. De Reamer

Introduction to Electrical Engineering.

Robert Page Ward—370 pp. $6.35. Prentice-Hall, Inc., New York, 1947.

This book was written as a text for a sophomore course in electrical engineering. Students taking the course are also taking physics and a first course in calculus. For this reason, the mathematics used in the book is limited in the earlier chapters to algebra and trigonometry and is extended in the later chapters to concepts of derivative and rate of change.

The MKS system of units is used throughout the book. A development of the CGS systems is included in the appendix.

Subject matter includes d-c circuit theory, measuring instruments, magnetic materials, magnetic circuits, induced and generated voltages, electromagnetic forces, electric field concepts, electrochemistry, and electronics. Many problems are given for each subject.

The book is an excellent text for an introductory college course in electrical engineering.

M. D. Horton

Very High Frequency Techniques, Vols. I and II

Compiled by the Staff of the Radio Research Laboratory of Harvard University—1057 pp. $14.00. McGraw-Hill Book Co., Inc., New York. 1947.

These two volumes comprise nearly 1100 pages, divided into 35 chapters, devoted mainly to three fields of interest—antennas, microwave tubes, and microwave receivers.

The books have a modest index supplemented by a well-arranged Table of Contents made up of chapter titles and subheads which will be of material assistance in locating general topics.

There is no pretense that these books are a comprehensive text. They are a summary of the work carried out during the war by and for the Radar Countermeasures Group, Division 15, National Defense Research Committee.

For this reason, the books are in the nature of an extensive technical report in which the authors have recorded a vast amount of detailed information. The text is generously illustrated by excellent line drawings which should prove particularly helpful. There is a wealth of practical information on measurement technique as well as much detailed information on the performance of specific systems and devices.

The books are definitely not for the beginner. However, the practicing design engineer and the research and development worker should find many cases where they will serve as valuable reference handbooks.

E. D. McArthur

Electric Motor Maintenance.

W. W. McCullough—126 pp. $2.00. John Wiley & Sons, Inc., New York. 1947.

This book presents recommendations for the maintenance and care of a wide range of electrical equipment including: induction, direct-current, synchronous, and gear motors; motor-generator sets; and electric couplings. The information is directed toward electricians and maintenance men who are directly responsible for the detailed care of motors. The suggestions, which are presented in nontechnical language, pertain to the prevention of trouble rather than to the design or major repair of motors.

The illustrations and much of the subject matter are based principally on apparatus manufactured by the Westinghouse Electric Corporation. Some of the statements and recommendations, particularly with respect to bearings and current collection, are a matter of opinion and do not fully apply to other well known makes of motors with different construction features.

The author first discusses such features as bearings, lubrication, current collection, and insulation and then repeats many of his statements in subsequent treatments of specific types of motors. The text would be better with less duplication.

The book should be of help and interest to practical men—in particular those who maintain and repair rotating electric apparatus.

E. R. Summers

Ultra- and Extreme-short Wave Reception.

M. J. O. Strutt—387 pp. $7.50. D. Van Nostrand Co., Inc., New York. 1947.

As might be expected, the great emphasis on electronics during the war has led to the publication of a large number of new technical books. Mr. Strutt's is among the many which suffer from an attempt to cover too much ground in one volume. However, the 409 references to other technical books and papers is probably adequate compensation for this defect.

The principal subjects treated are wave radiation and propagation, modulation, receiver noise, antennas, wave conductors and resonant devices, high-frequency instruments, and receivers. The treatment of noise is particularly interesting, and this very important subject is given its fair share of the available space.

In general, the book does not give the impression of up-to-dateness which is so apparent in many of the recent publications by American authors. The schematic diagrams illustrating various types of circuits would be more interesting if they were more modern and more complete. It should not be necessary to resort to the use of batteries to simplify circuits for the readers of this book.

Speaking of schematic diagrams, Mr. Strutt should be mildly chastised for permitting his resistor symbol to alternate between the rectangular block and the rectangular grid types. This little carelessness shakes one's confidence in the author.

H. F. Mayer

Waterbury's Handbook of Engineering.
(Fourth Edition)

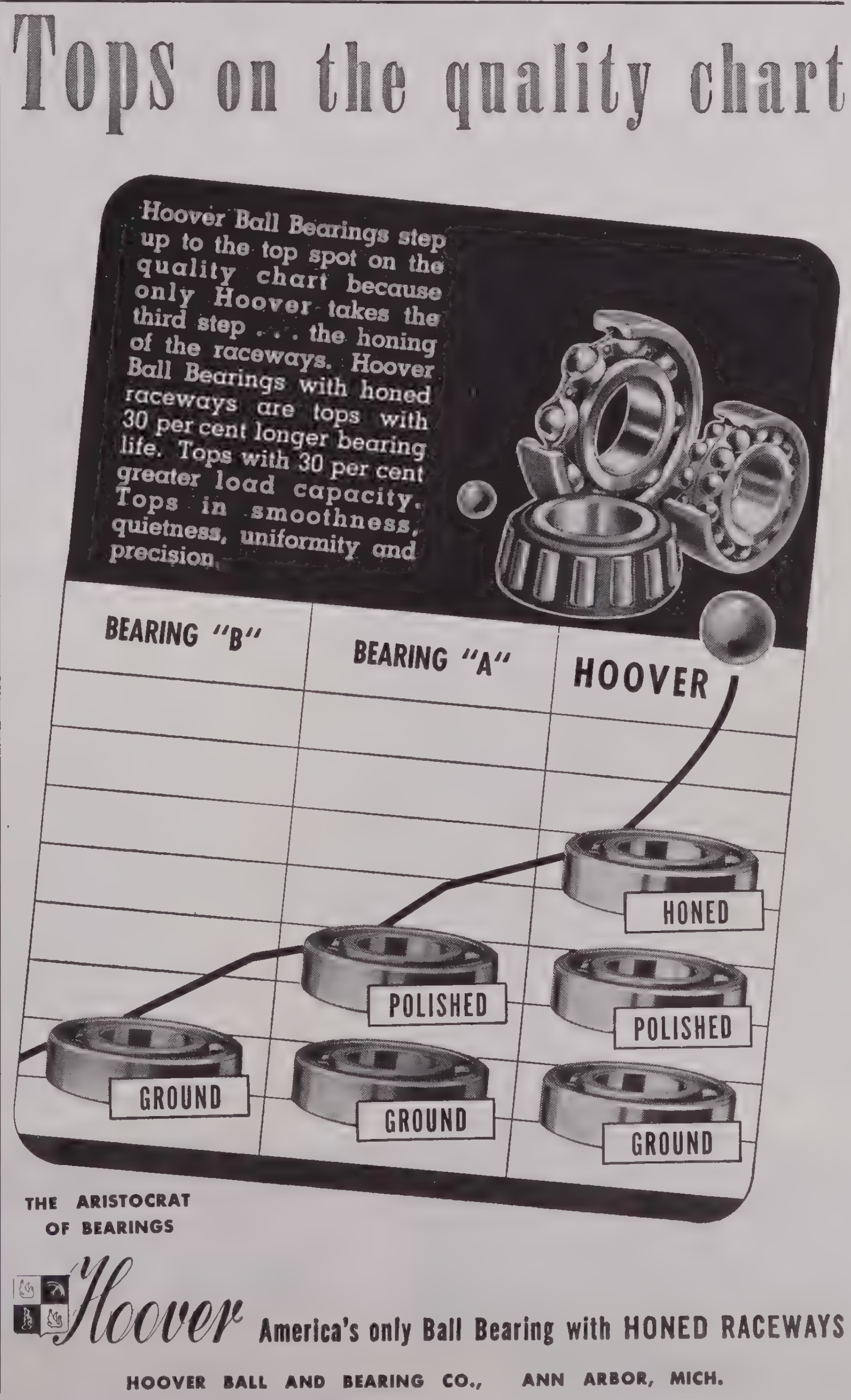
Revised by H. W. Reddick, W. M. Lansford, C. O. Mackey, H. H. Higbie, H. S. Bull—386 pp. 1947. John Wiley & Sons, Inc., New York. $2.50.

A handbook, to be of use to an engineer, should meet certain standards. The bulk of a good handbook should contain formulas and equations for use in general engineering practice, as well as the most commonly used numerical tables. It should use the symbols and notations that are the practice of the times. Explanatory literature should be short and concise. The contents should be so laid out that each section can be easily referred to with the minimum of effort—for example, the use of index tabs coupled with a complete table of contents of each section.

Waterbury's Handbook of Engineering is found to be well within the above standards, with a few exceptions. Its size makes it convenient for engineers to carry in a coat or vest pocket, although it may be too small for convenient handling. It is a handy book for use in the office. The contents are well laid out and contain a majority of the formulas, equations, and numerical tables needed for use in general engineering work, with two major exceptions: the table of natural logarithms and chemical equations and tables.

Field engineers, test men, students, and laboratory technicians will find this handbook useful for reference on the job. Engineering offices will probably find larger and more complete handbooks of better use in reference work.

D. C. Jackson, III



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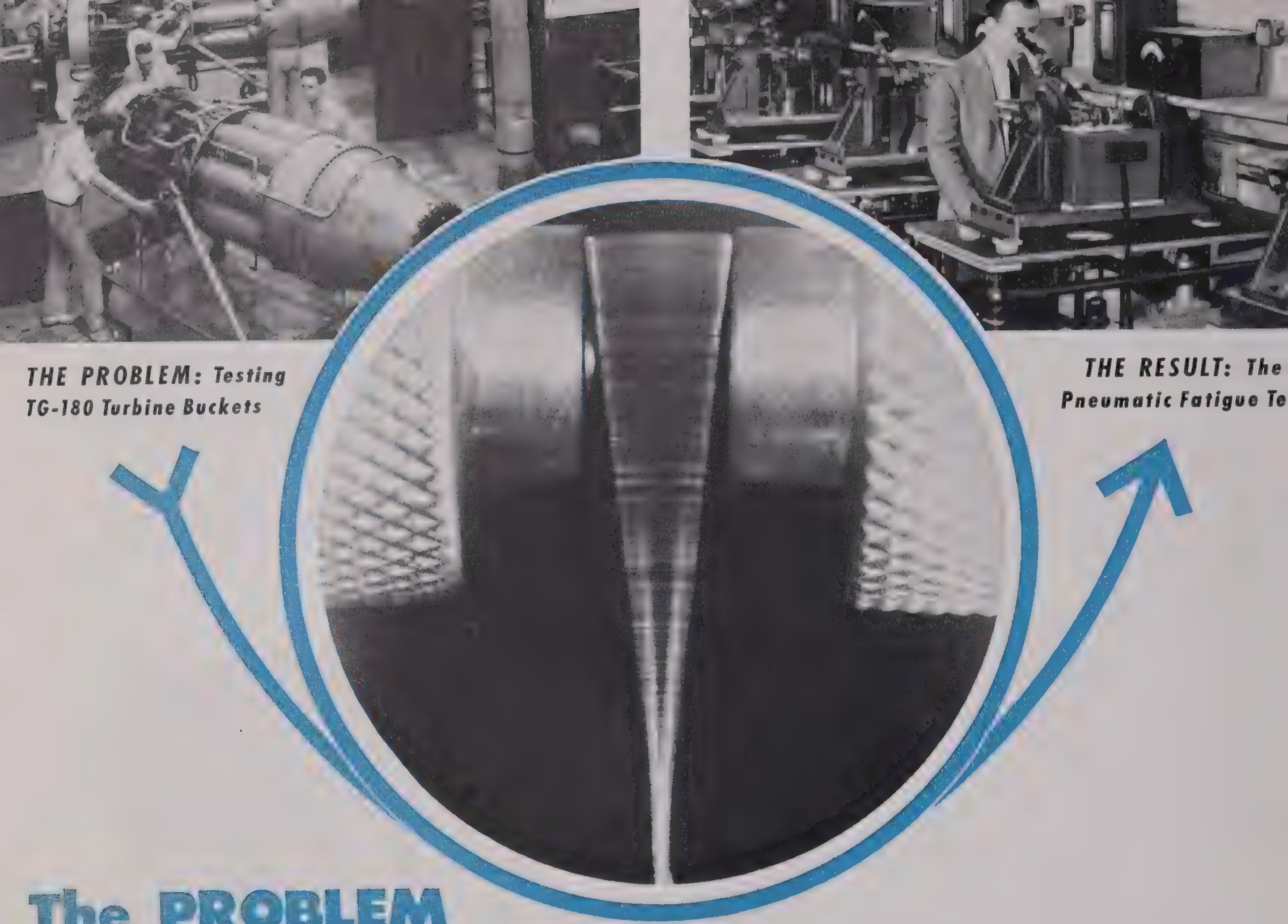

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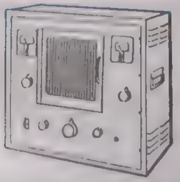

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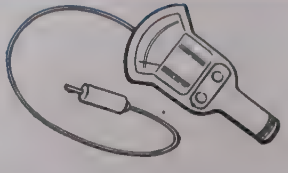

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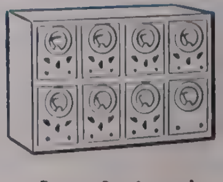

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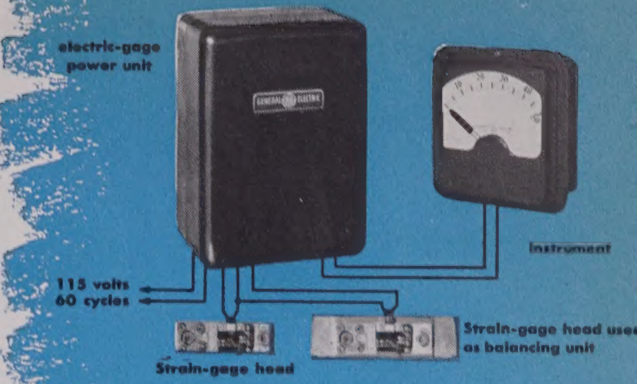

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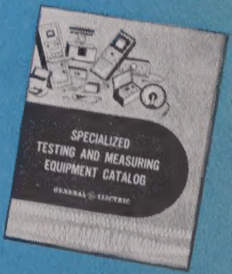

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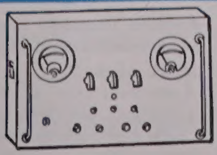

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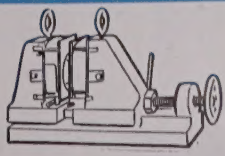
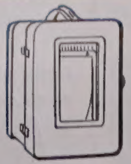


Magnetic Equipment



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Pressurization and Cabin Air Control.

W. M. Widgery—*Roy. Aero. Soc. Jour.*, Dec., 1947; v. 51, pp. 949-980.

The technical details and equipment involved in providing suitable cabin atmospheres for high-altitude airplane flight.

ALUMINUM

Carbides, Nitrides and Porosity in Aluminum.

Davidlee Von Ludwig—*Iron Age*, Nov. 20, 1947; v. 160, pp. 73-78, 141.

Contends that carbides and nitrides, rather than hydrogen, are the chief causes for porosity in aluminum alloys.

Resistance of Aluminum to Corrosion in Solutions Containing Various Anions and Cations.

A. B. McKee and R. H. Brown—*Corrosion*, Dec., 1947; v. 3, pp. 595-612.

AMPLIFIERS, MAGNETIC

Magnetic Amplifier Characteristics—Neutral Type.

Alan S. Fitzgerald—*Franklin Inst. Jour.*, Dec., 1947; v. 244, pp. 415-439.

BRONZE

Tin Bronzes; Effects of Impurities in the Chill-Cast Condition.

K. Winterton—*Metal Ind.* (Lond.), Dec.. 12, 1947; v. 71, pp. 479-482.

Results of investigations carried out on the effects of some common impurities on the casting, mechanical, and physical properties of nine bronzes.

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New Structural Diagram for Cast Iron.

H. Laplanche—*Metal Prog.*, Dec., 1947; v. 52, pp. 991-993.

Presents a new structural diagram conforming to present-day foundry conditions, relating the silicon, carbon, and cooling rate to the resulting microstructure.

Salvage of Cast Iron Through Heat Treatment.

Davidlee Von Ludwig—*Mat. & Methods*, Nov., 1947; v. 26, pp. 87-89.

How certain undesirable characteristics of cast iron as an engineering material can be overcome by subjecting it to heat treatment.

CLUTCHES

Controlled Friction Between Disk-clutch Elements Precisely Limits Torque and Eliminates Undesirable Vibration.

Elmer O. Peters—*Mach. Design*, Nov., 1947; v. 19, pp. 117-119.

On the design of a friction clutch such as that employed with series motors used in aircraft engine starters.

CONDENSERS, STEAM

Steam Condensers With Rolled-in Tubes.

W. H. Dunkley—*Engng.*, Dec. 19, 1947; v. 164, pp. 592-594.

CORROSION

Corrosion of Metals With Oxygen Depolarization.

Lt. Metals, Dec., 1947; v. 10, pp. 637-645.

The first part of a serial article based on a Russian book by N. D. Tomashoff.

DAYLIGHT

Solar Radiation.

Jack T. Wilson—*Elec. Engng.*, Dec., 1947; v. 66, pp. 1209-1213.

ELECTRIC LIGHTING

1947 Progress Report of the Illuminating Engineering Society, Committee on Progress.

E. D. Tillson—*Illum. Engng.*, Dec., 1947; v. 42, pp. 955-998.

A well-illustrated summary of progress in electric lighting methods and equipment, and in illuminating engineering practice.

ELECTRIC LIGHTING—SCHOOLS

An Architect Sees Lighting.

Lawrence B. Perkins—*Illum. Engng.*, Dec., 1947; v. 42, pp. 1049-1054.

Some general principles of school lighting as seen by the architect.

ELECTRON OPTICS

Experimental Electron Microscope for 400 Kilovolts.

A. C. van Dorsten and others—*Philips Tech. Rev.*, no. 7, 1947; v. 9, pp. 193-201.

FLOW METERS

An Electric Flow Meter

J. H. Laub—*Elec. Engng.*, Dec., 1947; v. 66, pp. 1216-1219.

A new instrument for accurately measuring, recording, and controlling the rate of flow, as well as the total flow, of fluids applies an electrocaloric principle.

FOUNDRY PRACTICE

Why Cast Steel Centrifugally?

J. F. B. Jackson—*Iron Age*, Nov. 27, 1947; v. 160, pp. 64-69.

A balanced assessment, from a British viewpoint, of the advantages and limitations of centrifugal casting of steel.

FRICTION

Radioactive Tracers in Friction Studies.

J. T. Burwell, Jr.—*Nucleonics*, Dec., 1947; v. 1, pp. 38-50.

Detailed analysis of new results, experimental techniques, and principles of friction studies with radioactive isotopes. Applications to study of lubricants, metal wear, and other well-known but unexplained phenomena are suggested.

HARDNESS—TESTING

Simplified Warm Hardness Test for Temperatures Below 700°F.

A. L. Pranses—*Instruments*, Nov., 1947; v. 20, pp. 1006, 1066.

To determine the hardness of various steels at temperatures intermediate between room temperature and the lower critical.

INSULATION

Synthetics as Insulants for Cables.

E. D. Bent—*Elec. News & Engng.*, Nov. 15, 1947; v. 56, pp. 38-41, 86.

The role of the various types of synthetics used in the design and manufacture of electric cables. The making of synthetics is considered as well as their properties.

LUBRICATION AND LUBRICANTS

Flow Properties of Lubricating Greases—Relationship of Apparent Viscosity.

Lubrication, Dec., 1947; v. 33, pp. 129-140.

Describes laboratory work which has attempted to relate apparent viscosity to low-temperature torque, low-temperature consistency, and the dispensing characteristics.

MEASUREMENTS, PHYSICAL

What Size Is Hot Work?

L. W. Macomber and C. N. Weiler—*Am. Mach.*, Nov. 20, 1947; v. 91, pp. 101-104.

Both warm weather and operating heat must be considered when making close fits with aluminum and magnesium. Methods of machine-shop measurement that take account of temperature of the work-piece are explained.

MEASURING INSTRUMENTS

The Quantometer—A Tool for the Metallurgist.

Walter Bonsack—*Metal Prog.*, Dec., 1947; v. 52, pp. 975-978.

A direct-reading spectrometer speeds the quantitative analysis of light metal alloys for 20 individual elements.

Precision Ultrasonic Interferometer for Liquids and Some Velocities in Heavy Water.

D. R. McMillan, Jr. and R. T. Legemann—*Acoustical Soc. of Am. Jour.*, Nov., 1947; v. 19, pp. 956-960.

An acoustic interferometer of improved design and the associated electronic circuit for measurement of ultrasonic velocities in liquids are described.

METAL CUTTING (MACHINE TOOLS)

Cast Alloys Vary in Cutting Efficiency.

J. B. Dym and T. Badger—*Am. Mach.*, Nov. 20, 1947; v. 91, pp. 109-111.

Extensive investigation on tool breakdown, life, speed and feed change, interrupted cuts, and tool grinding showed wide variation between materials.

MICA

A Mechanical Mica Splitter.

Nat. Bur. Stds. Tech. News Bul., Nov., 1947; v. 31, pp. 128-129.

Short, illustrated description of a machine developed by the Bureau of Standards.

NUCLEONICS

The Atom and Its Nucleus.

J. J. Smith—*Elec. Engng.*, Dec., 1947; v. 66, pp. 1165-1175.

The first article of a series which will include such timely subjects as nuclear engineering, production of high-energy particles, isotope separation, nuclear piles, and health hazards.

PARTICLES

Mathematical Description of Certain Breakage Mechanisms Leading to the Logarithmico-normal Distribution.

Benjamin Epstein—*Franklin Inst. Jour.*, Dec., 1947; v. 244, pp. 471-477.

An attempt to explain, by the use of a statistical model, an apparent phenomenon of particle size distribution occurring when solids are broken up.

PHOTOGRAPHY

Survey of the Application of Photography in Naval Research, Testing, and Development.

J. H. Bell and W. R. Cronenwett—*Soc. Motion Pict. Engrs. Jour.*, Dec., 1947; v. 49, pp. 494-505.

A survey to determine to what extent the various bureaus and offices of the Navy utilize photography to record, supplement, and document information and findings.

PHOTOTUBES

Sensitivity of Various Phototubes as a Function of the Color Temperature of the Light Source.

A. Cramwinckel—*Soc. Motion Pict. Engrs. Jour.*, Dec., 1947; v. 49, pp. 523-529.

A measuring method and measurements for ascertaining the sensitivity of different types of phototubes.

POWER PLANTS, ELECTRIC

Shortages of Reserve Capacity Tax Systems, Capabilities.

Elec. Wld., Nov. 22, 1947; v. 128, pp. 74-77.

Results of a survey of the country's power-generating capabilities.

RADIO ENGINEERING

High-powered R-F Linear Amplifiers.

C. W. Corbett—*Communications*, Nov., 1947; v. 27, pp. 22-25, 34-36.

A description of circuits designed to provide kilowatts of RF power in AM transmitters with low distortion, low residual noise and high fidelity. Includes an impedance inverting network in the Doherty circuit.

SEMICONDUCTORS

Semiconductors With Large Negative Temperature Coefficient of Resistance.

E. J. W. Verwey and others—*Philips Tech. Rev.*, no. 8, 1947/1948; v. 9, pp. 239-248.

The development of resistor materials made of such conductors.

STEEL

Anisothermal Formation of Bainite and Proeutectoid Constituents in Steels.

Leonard D. Jaffe—*Metals Tech.*, Dec., 1947; v. 14, Tech. Pub. no. 2290, 14 pp.

Flame Hardening of Armor Plate.

E. L. Bartholomew, Jr. and others—*Metal Prog.*, Dec., 1947; v. 52, pp. 979-983.

Flame-hardening of the surface of low-alloy armor plate by successive passes of a torch 6 in. wide was found to produce a hardened case, uniformly 0.25 to 0.30 in. deep.

Controlled Vacuum Heat Treating.

Steel, Nov. 24, 1947; v. 121, pp. 80-83.

Results of American Gas Association experiments, while positive in nature, do not apparently lead to any new commercial processes.

Recent Developments in Steel Processing.

J. A. Kilby and W. G. Cameron—*Inst. Engrs. & Shipbldrs. Trans.*, Dec., 1947; v. 91, pp. 81-136.

Equipment and methods for rolling steel.

SUBSTATIONS

Planned Substations Can Cost Less.

E. V. Sayles—*Elec. Wld.*, Nov. 22, 1947; v. 128, pp. 82-84.

How planning and detailed design are facilitated by assigned style numbers and field assembly speeded with standard parts from stock.

TRANSFORMERS

Stepped Core Sections for Power Transformers.

A. Langley Morris—*Engr.*, Dec. 19, 1947; v. 184, pp. 581-583.

Their theory and design.

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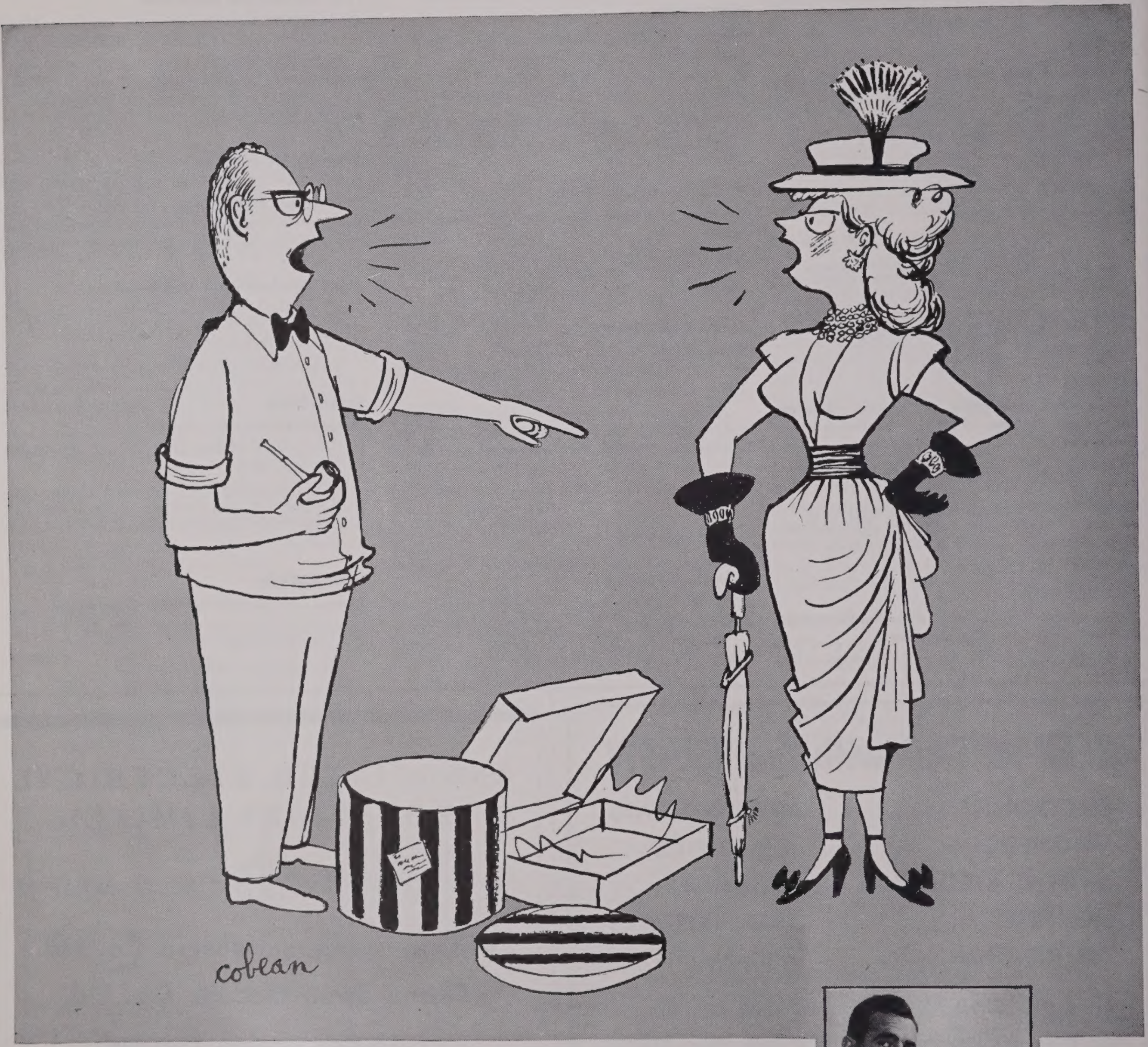

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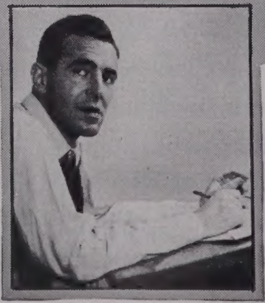

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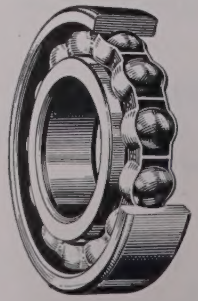

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